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Future Prosoects of FA-From FA to IMS

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FACTORY AUTOMATION, ROBOTICS

Future Prospects of FA—From FA to IMS

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[Text]

1. Introduction

(1) The term FA (factory automation) is "made-in-Japan" English that was coined here in the mid-1970's; it means the automation of manufacturing processes using industrial robots, NC machine tools, automatic transport vehicles and so on. So far FA has been introduced primarily into large companies. But with the recent, rapid technological advances in the use of electronic information and networks, there has been a trend toward integration of all company activities, as represented by the concept of CIM (computer integrated manufacturing). A period of major change is approaching. Consequently, this discussion group has been established for the purpose of redefining and comprehensively debating company activity as a whole, starting with the automation of the production site that is conventionally called FA, and including orders, design and development, sales and servicing.

(2) At one time Japan had to rely on trade with foreign countries because it had little territory, high population density and few natural resources such as oil and coal. Thus maintaining a sound manufacturing sector was a factor that was indispensable to Japanese economic progress. Japan's manufacturing sector has followed the advanced countries of Europe and the United States; as a result of the unflagging efforts of its people, it has achieved a high rate of economic growth and has reached the world's top levels of economic strength and manufacturing technology strength. Japan now accounts for more than 10 percent of world GNP and has become able to exert more than a little influence in the world. For that reason Japan is now asked to make the international contribution expected of an economic power.

(3) Japan's social abundance, the changing view of psychological and cultural abundance in its social awareness, and the diversification of consumer needs have made job shop type production a necessity. The labor climate is also changing, and in the midst of the aging of the population, higher educational attainments, greater involvment of women in society, the shortening of work hours and the departure of new graduates from the manufacturing sector, there is a need for more emphasis on human factors and more efficient manufacturing systems. FA is a response to that need. Improvement of high technology and information processing technology, which is represented by the progress of microelectronics and which can be called the third industrial revolution will enable formation of FA systems to support that response.

(4) Moreover, the spread of FA has made it possible to manufacture things which could not be manufactured previously. In the production of semiconductors, for example, limits had been imposed by the need for human presence, but the introduction of FA enabled extremely detailed processing and extremely clean environs, making it possible to manufacture semiconductors with high levels of integration. The contribution these unprecedented new products have made to the abundance of the society is an aspect that cannot be overlooked.

(5) On the other hand, Japan's encouragement of FA has brought about a reduction of product costs and increased exports, thus leaving the potential for intensified trade friction. Fundamentally, though, it is the responsibility of the manufacturing industry to provide products with "quality, prices and delivery dates" that satisfy the consumer. Moreover, the manufacturing industry should use FA to originate new products and contribute to an improved standard of living for all people. If promotion of FA raises productivity, cuts costs and also brings on a flood of exports, trade friction will intensify for a while. But if the promotion of FA will bring about future abundance for all people, then it is an important responsibility for Japan.

(6) For Japan to play a positive international role based on FA technology, it will be necessary to further encourage standardization, within the country, in those fields of FA in which Japan is technologically advanced. It will also be necessary to actively promote international standardization through entities like the ISO (International Organization for Standardization), and to carry out international technical exchanges and transfer of technology, thus contributing to the whole world.

(7) For Japan to establish a foundation for the long-term development of industry and for the whole world to develop, it must contribute to international cooperation and to the international community, it must maintain industrial vitality by demonstrating creativity, and it must also create a new life culture, all while responding rapidly and accurately to a variety of changes. And so it must promote FA to enable achievement of a worldwide "plus sum."

(8) Under such circumstances, it has become very important that we convene the FA Vision Discussion Group, assemble men of learning and experience from all relevant sectors, and debate both the future prospects of FA and the policies of MITI.

2. What is FA

2.1 The Definition of FA and its Fields

Japan's machine industry led the world in advocating FA; it is a concept that has comprehensively grasped the directions of improvement in the manufacturing industry and manufacturing technology. The term is "made-in-Japan English," but it is widely recognized as comprehensively expressing the manufacturing industry and manufacturing technology.

Figure 2-1. Example of FA Factory

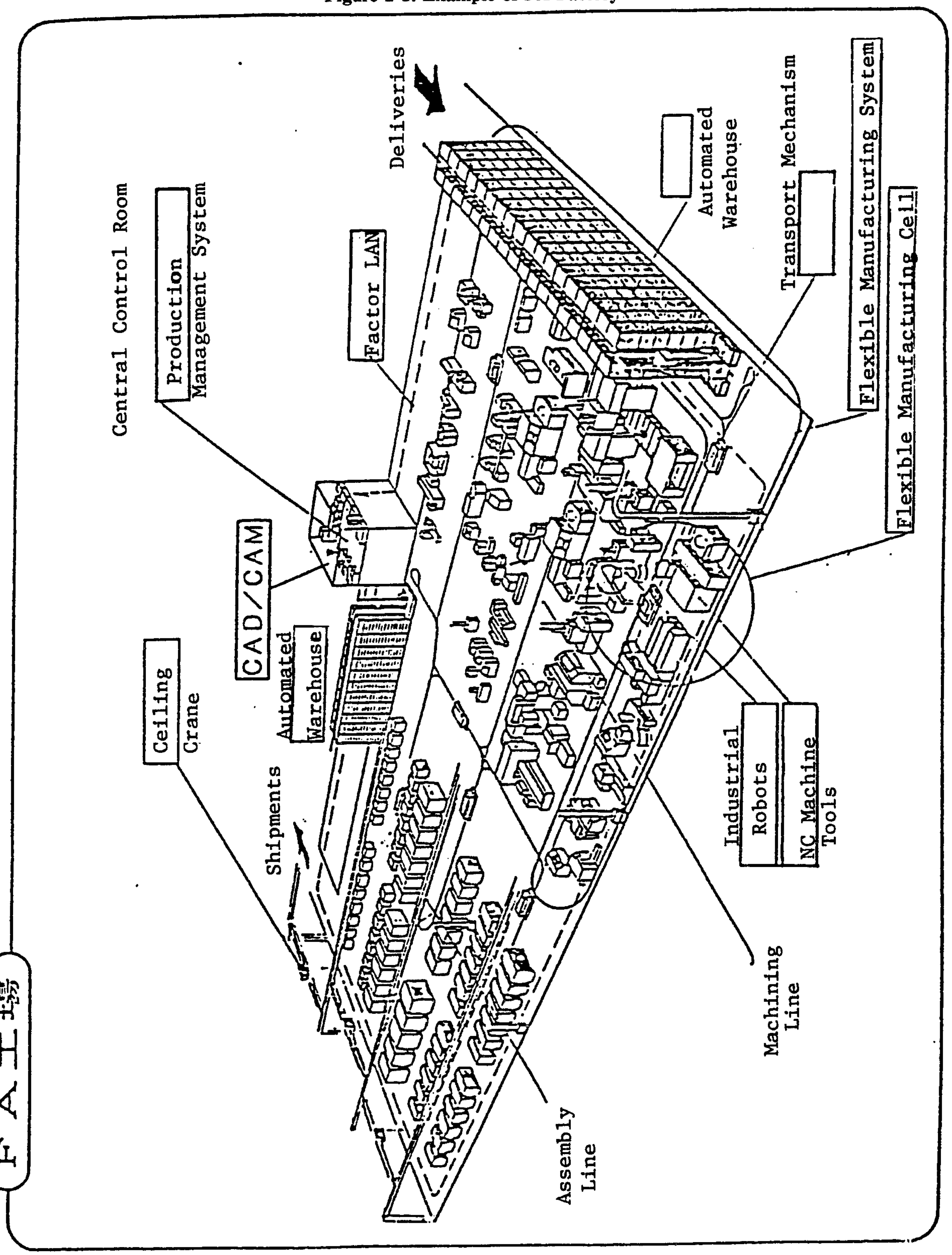
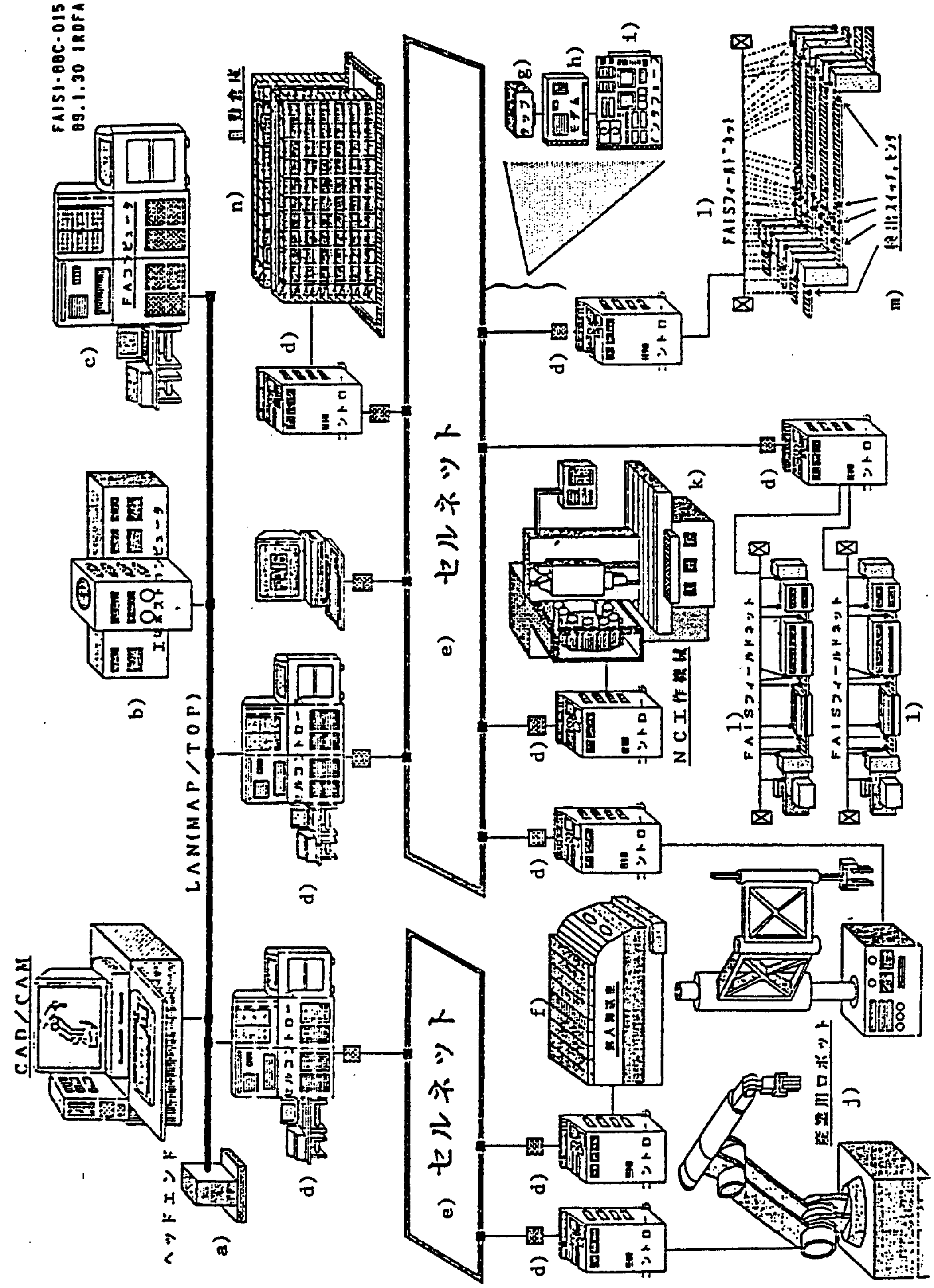


Figure 2-2. Components of FA System



Key:—(a) Head end—(b) Factory host computer—(c) FA computer—(d) Controller—(e) Cell net—(f) Automatic guided vehicle—(g) Tap—(h) Modem—(i) Interface—(j) Industrial robots—(k) NC machine tool—(l) FAIS field net—(m) Inspection switch center—(n) Automated warehouse

At first, FA was aimed at factories in machining and assembly industries, and referred to the automation of facilities and computerization of design and management processes. At present, however, FA has come to be promoted in a broad range of manufacturing industries in addition to machining and assembly. The importance of FA has also been recognized from the perspective of improved efficiency and coordination between factories and outside entities.

FA has heretofore been a concept of automation that incorporated three kinds of "FA:" factory automation, which means automation of the entire factory, flexible automation, which means automation capable of job shop type production, and flow automation, which means automation of the flow of information and goods.

The definition of FA in this discussion group, taken broadly, is as follows: FA is the integration of all production activities and improvement of productivity based on flexible automation of the factory.

Now, this definition includes CIM (computer-integrated manufacturing), which aims at integration of functions within the company by means of information and communications networks.

2.2 The Development of FA

From the industrial revolution until the present, manufacturing processes have been automated with the goals of improving productivity and improving quality. Against this background, automation technology has made great progress through changes in social needs and technical innovation in various fields of production.

The first period of automation had the goal of mass production as represented by the automobile industry of the 1950's. The word "automation" was used for the vigorous introduction of lines to produce large quantities of goods.

In recent years automation has come to include job shop type production; the main current has come to be creation of systems that fuse NC machine tools, robots and so on with information machines, represented by computers.

NC machine tools began with the NC milling machine developed at MIT (Massachusetts Institute of Technology) in 1952 and the machining center developed in 1958 by the Cross and Trecker Co. of the United States. Machining centers were being introduced in Japan in the mid-1960's, primarily by large enterprises, and now numerical control has been applied to all sorts of machine tools.

Moves to form machinery into systems were seen in the unmanned jobshop type parts processing system of Britain's Mullins Co. in 1967, the flexible manufacturing system of Cincinnati-Milacron that year, and the Japanese National Railway's gang-control system for repair of car parts in 1968. Then at the start of the 1980's, automation of production sites expanded further with a sudden boom in FMS (flexible manufacturing systems) that resulted from the spread of mechatronics based on microelectronics.

Moreover, the remarkable development of information, communications and computers has made it possible to attempt everything from the automation of local manufacturing processes to integration of entire production sites, including the flow of information regarding orders, design, fabrication and shipment.

In that context, the importance of information and communications is ever increasing. In the world of communications protocols, for example, worldwide standardization of the sort seen in MAP (manufacturing automation protocol)/TOP (technical and office protocol) has moved forward positively, in advance of product development.

Within this process of the development of automation, the term "FA" (factory automation) was coined in the beginning of the 1980's when there began to be discussion of automation that would enable unitary processing of the information from various levels within the factory. Although in Japan the term used to discuss factory automation was usually FA, the concept of CIM was usually brought up in Europe and the United States.

2.3 The Goals of FA

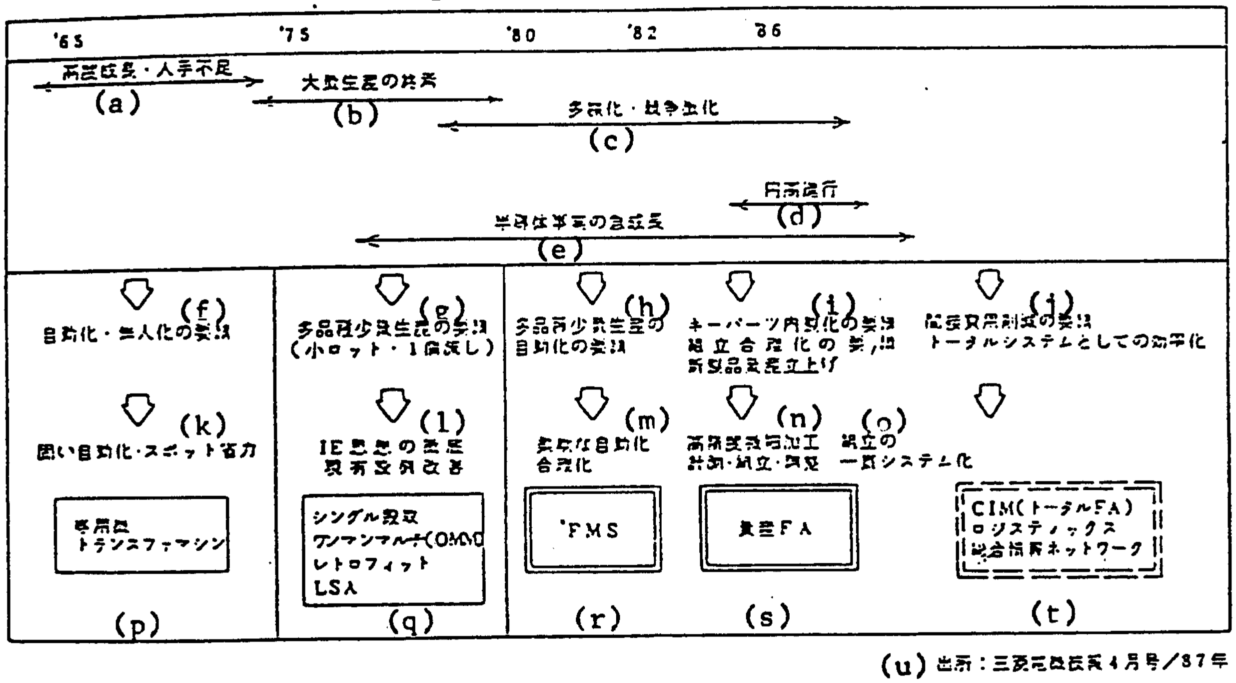
The goal of companies with regard to FA, set in consideration of changes in the environment surrounding them as they quickly grasped various social background factors such as diversification of consumers' needs, has been to strengthen the market competitiveness of their products by producing higher added value and improving company structure.

In the technological background for this there have been technological innovations represented by microelectronics, and the augmentation of FA systems.

Within this context, the specific goals for goals sought in FA include such things as (1) job shop type production that responds to the needs of consumers, (2) reduction of lead time, (3) reduction of inventories (4) improvement of product quality and reliability, (5) unmanned, nightime operation and improved capacity utilization, (6) strengthened information management to support organized utilization of company resources and rapid, accurate decision making by managers, (7) improvement of safety and the work environment, and reduction of human error in information processing and transmission, and (8) realization of efficient management, from a global perspective, of the individual company or company group. The weights assigned to these goals depends on the industrial sector, the scale of operations, management policies and so forth.

And as technology has improved and become more complex, there are increasing numbers of companies whose goal for FA is the accomplishment of operations

Figure 2-3. Course of Development of FA



Key:—(a) Rapid growth, worker shortage—(b) Era of mass production—(c) Diversification and increased competition—(d) Stronger yen—(e) Rapid growth of semiconductors—(f) Automation and unmanned devices—(g) Job shop type production (small lots, quick product changes)—(h) Automatic equipment for job shop type production—(i) In-house production of key parts, rationalization of assembly, development of new products—(j) Indirect application system, efficiency of total system—(k) Old automation, spot labor savings—(l) IE concept, improvement of existing facilities—(m) Flexible automation, rationalization—(n) Highly automated machining and assembly—(o) Systematization of assembly—(p) Specialized transfer machines—(q) Single-stage, One-man Multi (position) retrofitting—(r) FMS—(s) Basic FA—(t) CIM (total FA), logistics, comprehensive information networks—(u) Source: Mitsubishi Electric Report, April 1987

that cannot be done by the human hand, such as micromachining, prevention of impurities and assurance of uniform quality in the semiconductor industry.

3. Trends of FA

3.1 Trends of FA-related Industries

3.1.1 Positioning of FA-related Industries

FA-related industries can be roughly divided into FA machinery industries and FA system industries. Many FA machinery industries have been established, and have a long history. Considered by type of processing, there are machining tools, robots that perform assembly, unmanned vehicles to transport goods, and automated warehouses that store and control parts and tools.

In the flow of information to manage machinery, information is output by the sensors that detect such things as temperature and position, by measuring equipment, and by control equipment that controls individual machines, and it is transmitted to an FA computer that performs information processing.

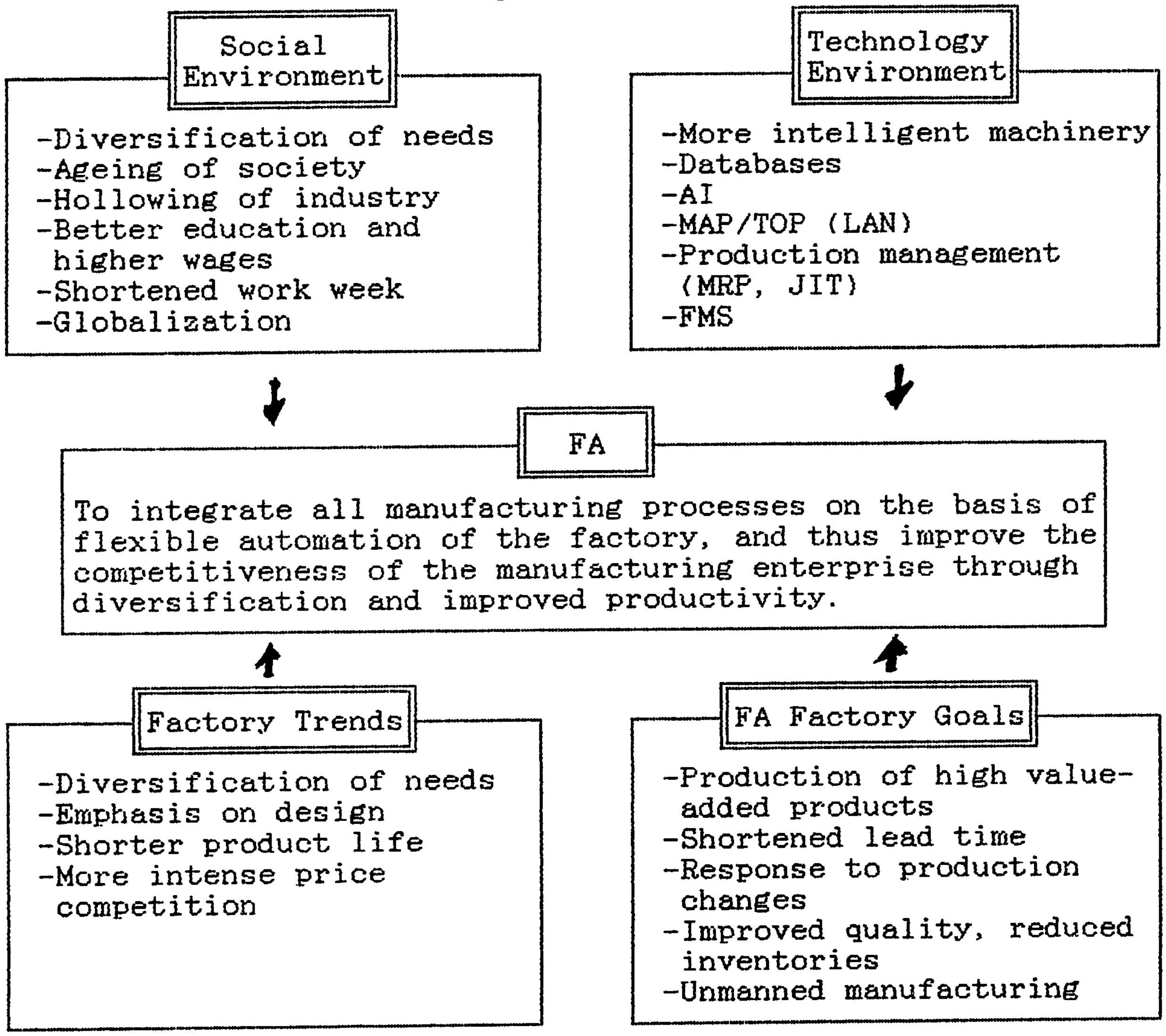
In addition to that equipment, there is now CAD (computer-aided design)equipment that automates design, CAM (computer-aided manufacturing) and CAE (computer-aided engineering) equipment that supports manufacturing and engineering.

On the other hand, very few FA engineering industries have been established at present. There are, however, prospects for future growth. One such industry, factory LAN's (local area networks), integrates communications among FA machinery, and FA engineering is a matter of planning introduction of the optimum system for a factory, carrying out design, construction and operation of FA.

3.1.2 NC Machine Tools

NC (numerical control) machine tools are defined as numerically controlled machines that remove unwanted protions from workpieces by cutting, grinding etc, and give them the desired shape. They were developed in the United States in 1952, bringing on a revolutionary change in manufacturing methods. Since then many

Figure 2-4. Goals of FA



types of NC machine tools have been developed, and have spread rapidly in the automobile and electrical machinery industries.

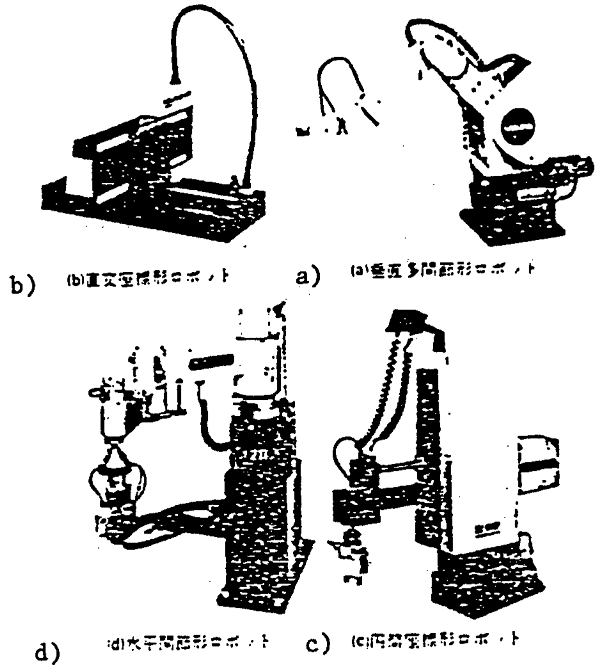
Japanese production of machine tools grew about five-fold in the ten years beginning in 1975. Production in 1988 amounted to about ¥880 billion. At present, NC machine tools account for about 70% of all machine tools, on the basis of units delivered.

If 1989 production is considered by type, NC lathes made up 23% (¥203.2 billion) and machining centers made up 23% (¥206.8 billion). These two alone accounted for nearly half of production, and thus were strategic types for each type. The number of FMS (automated systems for cutting and machining, built around NC machine tools) now operating in Japan is said to be from 200 to 400 systems. The broad range of this value reflects the lack of an established definition of FMS (that is, should FTL (flexible transfer lines) and FMC (flexible manufacturing cells) be included or not?) and the increasing number of cases of machine tool users putting together their own systems. It is thus difficult to grasp the actual situation.

According to the "Statistical Survey of Machine Tool Facilities" MITI carried out in 1987, a total of 259 FMS had been set up, of which 188 systems were cutting and machining FMS. But because of the difficult of obtaining complete information, it is thought that there are considerably more. In any case, FMS have been introduced into all industries, and their number is expected to rise steadily because of their very high economic efficiency.

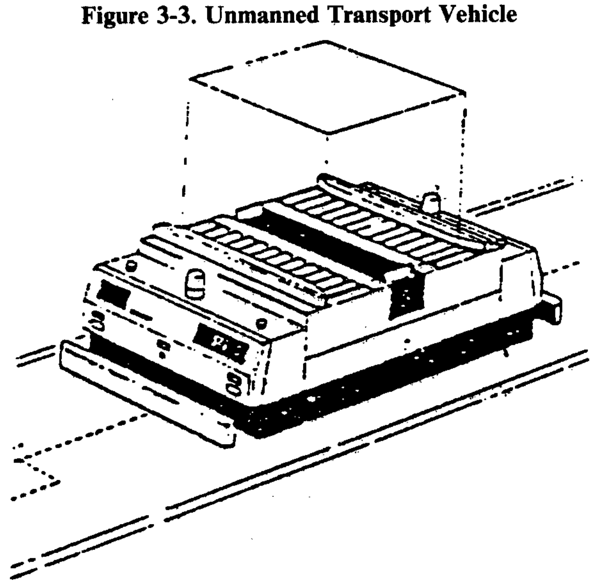
Up till now, machine tools have been typical of FA, on the point of performing processes like cutting for the machining and assembly industries, and future growth can be anticipated. But because of trade friction (such as the voluntary quantitative restrictions with the United States), it is difficult to predict growth overseas. As for domestic demand, the demand for machine tools is largely dependent on the trend of plant investment, and so stable growth, based on rationalization through private plant investment, can be expected for some time.

Figure 3-2. Types of Robot



Key:—(a) Vertical, multi-articulated robot—(b) Linear cordinate robot—(c) Radial coordinate robot—(d) Horizontal, articulated robot

Figure 3-3. Unmanned Transport Vehicle



3.1.3 Industrial Robots

Industrial robots are defined as machines with automatically controlled manipulation or motion functions, which execute different types of work in accordance with programs, and which are used in industry.

The first of these was the playback robot developed in the United States in 1962; 1967 was the occasion for importation into Japan. Since then they have continued to be introduced, especially in the automotive industry. They have made a great contribution to improved productivity, and they have shown growth as machinery that can do jobs like welding and painting that are hazardous for humans.

Production of industrial robots grew 27-fold in the ten years beginning in 1975; it reached about ¥370 billion in 1988. 1988 exports acounted for about 20% of production (about ¥75 billion). There were hardly any imports (less than ¥2 billion). Japanese industrial robots make up about 60% of units operating throughout the world; Japan is first in the world in that respect.

In addition to electric and electronic instrument production, automobile production and general machinery production, the leading industries in introduction of FA, there is a concentration of demand for industrial robots in the polymer molding and forming industry. It is expected that demand will increase for assembly processes in electric and electronic assembly production. Demand is also expected to expand in a broad range of production fields including metal products, food products, wood and wood products, chemicals and steel, and to increase in such new, nonmanufacturing fields as atomic energy, marine development and construction.

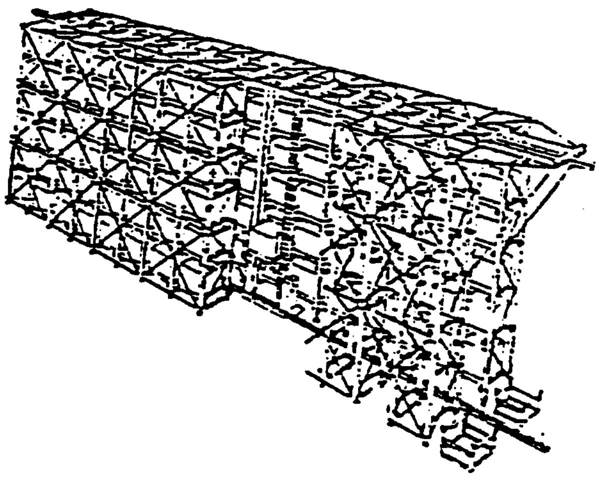
3.1.4 Transport and Material Handling Machines

Transport and material handling machines have been developed in Japan as FA-related machines, riding the crest of the wave of conversion to FA. The automatic warehouse and the unmanned transport vehicle can be offered as representatives of this category.

Within the flow of conversion to systems in the factory, the automatic warehouse has spread since 1965, and unmanned transport vehicles have been introduced as a classic form of FMS and FA automatic transport systems since 1975. With the steady growth of FMS, especially, many unmanned transport vehicles have been introduced for transport of work in machining systems, transport of parts in assembly systems, and for supply purposes.

The combined production of transport and material handling equipment is thought to have broken through the ¥200 billion level in 1988, and there are good

Figure 3-4. Automated Warehouse



chances for continued growth of unmanned transport vehicles and slight growth of automated warehouses. Demand for automated warehouses was about ¥35 billion in 1987, about five-fold growth over a ten year poriod. Demand for unmanned transport vehicles grew ten-fold over ten years, in terms of the number of units, and is expected to exceed ¥10 billion in 1989.

The functions of transport and material handling in FA are to supply materials to manufacturing processes (machining and assembly), to facilitate connections among manufacturing processes and to retrieve the manufactured goods. These functions are a basic element of FA in the sense that they connect all stages of the long process from the beginning of manufacturing to its end, from inspection of materials received through machining, assembly and shipping inspection. For that reason, future growth can be expected as FA spreads. But because the export ratio is low, growth will be largely dependent on the trend of domestic plant investment.

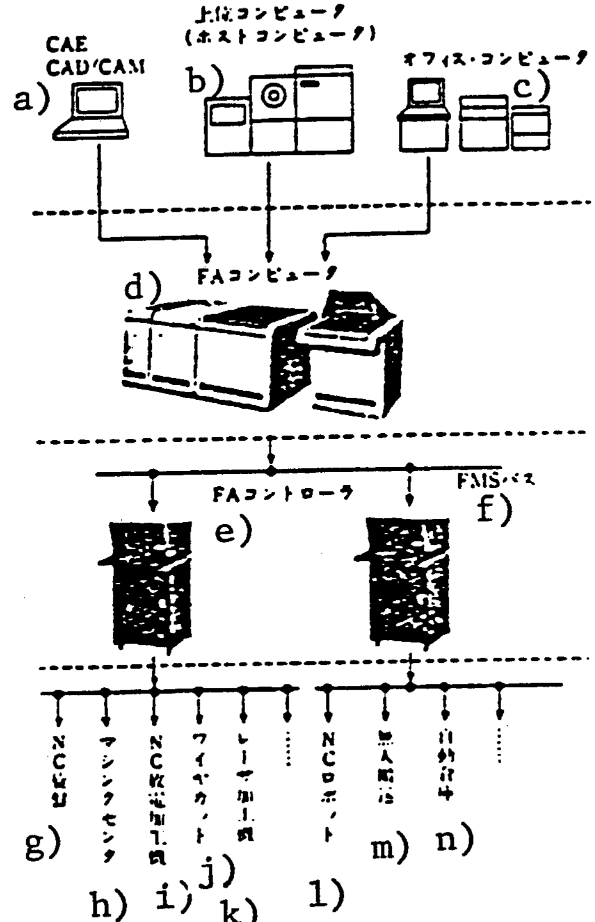
3.1.5 FA Computers

Computers used in FA consist of all-company (host) computers (the production management level), factory computers (the shop floor level) and local cell computers (the line management and control level).

The use of computers in automation of the manufacturing industry became practical in the 1960's, beginning with batch operations in the accounting field. That was followed, during the period of rapid growth of secondary industries, by the establishment of PA (process automation) technology for computers used for control in the fields of steel, petroleum and chemical plants.

The 1980's saw development from localized automation of machining, assembly, inspection and transport/ distribution to the level of total systems. In recent years there has been rapid expansion of the use of computers for total FA, regardless of the scope of the company, in such fields as the food, appliance and machinery industries.

Figure 3-5. FA Computers



Key:—(a) CAE/CAD/CAM—(b) Upper level (host) computer—(c) Office computer—(d) FA computer—(e) FA controller—(f) FMS bus—(g) NC device—(h) Machining center—(i) NC electrostatic processor—(j) Wire cutter—(k) Laser processor (l) NC robot—(m) Unmanned transport—(n) Automatic warehouse

The major premise of FA is that goods and information flow and are processed as a pair. Control computers were used to automate factory facilities for the flow of goods, and office/business computers were used to manage the flow of information. Then, with the spread of FA into more fields of industry and the development of microprocessor technology, computers were wanted that could integrate the regions of "goods" and "information," and process them simultaneously. The result was the concept of the "FA computer."

It is expected that minicomputers used as FA computers will continue to show stable growth, supported by demand in the fields of communications control and technical design. In 1985 the market came to ¥200 billion, 4.5 times what it was ten years earlier, and it is thought to have reached ¥260 billion in 1988.

The establishment of information networks in the factory is fundamental to use of FA computers. They will be

adapted to MAP and OSI, and software portability will be accomodated. Stable growth can be anticipated in combination with the promotion of CIM in the manufacturing industry.

3.1.6 Instrumentation

Instrumentation for FA consists of sensors for system control, inspection, monitoring of facilities and systems, and dignosis of problems, together with system machinery. The remarkable innovations in the automation of inspection and testing—the upgrading of instrumentation technology—have contributed greatly to the spread of FA.

Production of FA instrumentation broke through the ¥100 billion level in 1988, and great demand is expected as factories become less oriented toward human workers.

In the assembly process, for example, instrumentation is used for laser measurement tied to the automation of assembly, and for the automated recognition (of barcodes) in FMS and transport systems. The history of full-scale adoption of such instrumentation is no more than ten years in length, but its spread has been spectacular. Visual inspection devices have been developed for use in graphic processing, and have begun to be used for the automation of visual inspection.

With the increased performance and size of facilities and systems, it has become necessary to operate systems at high efficiency and increase their reliability. That has made instrumentation for monitoring and diagnostics necessary, and the realization of automation of manufacturing processes and monitoring will require creation of information networks needed to determine and display process conditions and to assemble results.

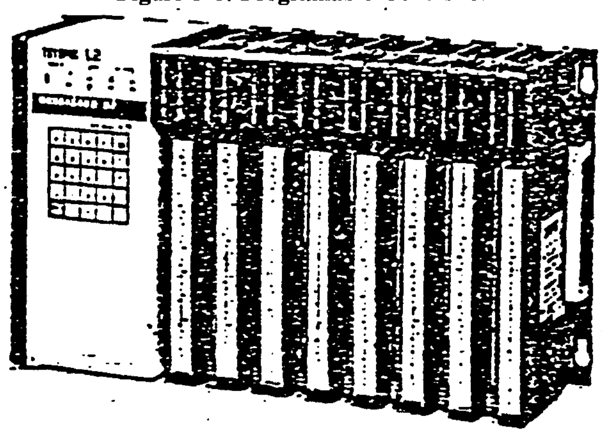
3.1.7 Controllers

Controllers are devices such as PC's (programable controllers), detectors, operating switches and control relays; they are indispensable to FA equipment and systems. PC's, which are particularly important in FA, are a type of sequence controller. The content of their controls is changable, and for the most part they are electronic, being built around microprocessors and other semiconductor devices. PC's appeared on the scene in 1969 as the electronic version of megnetic relays. They were subsequently made capable of logic control through the addition of CPU's (central processing units)

The scale of the market for controllers is about ¥500 billion all together. Within that market, PC's have grown about six-fold in then years, and are expected to climb to the ¥120 billion yen level in fiscal 1989.

PC's have a central presence in FA systems. In addition to their role of direct control of the FA components and machines which act as terminals, The advance of CIM has given them increasing importance as the equipment with the responsibility information processing at the lower level of stratified information systems. The reliability and value of the entire FA system are determined

Figure 3-6. Programable Controller



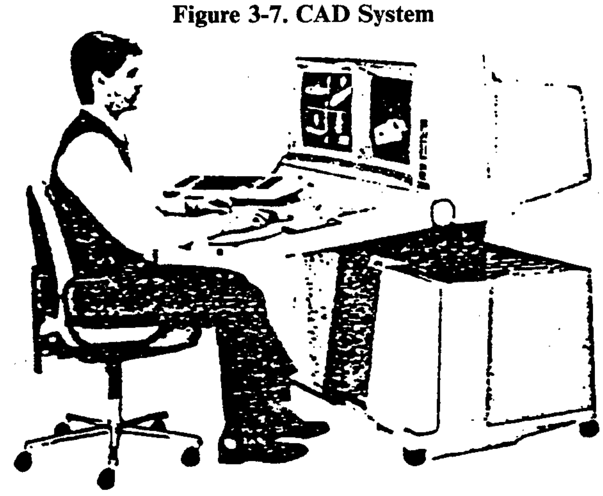
by the functions and reliability of its PC. Recently PC's have been integrated with other machines and equipment. For that reason, stable future growth is expected as the manufacturing industry increasingly turns to CIM.

3.1.8 CAD/CAM/CAE (Computer Assisted Design, Manufacturing and Engineering)

CAD, CAM and CAE are systems for design work, operational and process design for manufacturing, and prior evaluation of product capabilities and production processes for manufacturing, all aided by computer. CAM began with the use of an NC automatic programming system for NC machine tools in 1955, and CAD began with SKETCHPAD, developed at MIT in 1963. The development of CAE began with the fusion of CAD and CAM, the adoption of dialog-type drawing systems and solid modelling, and the establishment of analysis technology using the finite element method. CAE and CAD/CAM have spread rapidly.

Total sales of CAD/CAM systems in 1987 came to ¥300 billion, having grown four-fold in five years. 1988 sales are thought to have come to ¥450 billion. Many buyers are in the electrical machinery manufacturing and general machinery manufacturing industry, and many of the

Figure 3-7. CAD System



applications are mechanical design. Moreover, CAD for personal computers has shown rapid growth recently as the performance of personal computers has improved and their prices have dropped; sales in 1986 were up 72% over 1985. This is a marked tendency in the United States as well, and the scale of the graphics market is expected to exceed $1 billion by 1990.

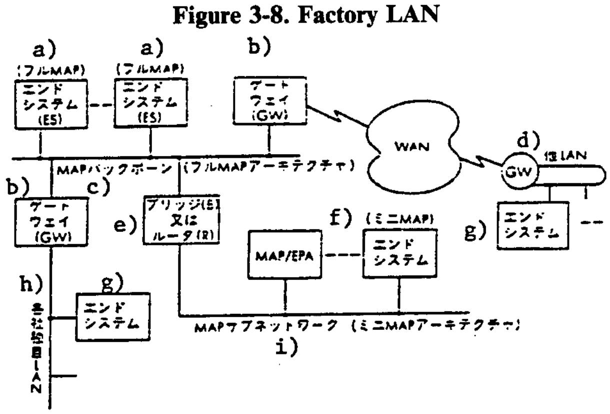
At present, attention is focused on the shift from CAD, which has been mostly a matter of product design, to the CAE approach which looks at production processes as a whole, as well as on the spread of CIM. More concretely, the development of CAD/CAM/CAE has encouraged shorter design time, higher design performance, higher reliability, more in-house design and lower design costs, and will encourage the move toward CIM by means of organic fusion with the manufacturing stage.

3.1.9 Factory LAN (local area network)

A factory LAN is defined as something that integrates, into one or more high-speed communication circuits, intercommunications among multiple devices with communications functions (such as computers, terminals and FA machines) that are distributed within a factory. The devices connected to a LAN have exclusive use of its communications circuit for short periods. LAN's are generally classified on the basis of three factors: topology, transmission medium and access method. The history of networks as factory LAN's goes back 20 years, but LAN's are new as an industry, and have been supplied by computer manufacturers, cable manufacturers and communications equipment manufacturers.

The industry is a small one at present, estimated to be somewhat over ¥1 billion. But because FA cannot succeed without LAN's, it is an important industry. So far, however, only the hardware technology has been established by the industry. Communications software technology and

Figure 3-8. Factory LAN



Key:—(a) (full MAP) End system—(b) Gateway—(c) MAP backbone (full MAP architecture)—(d) Other LAN—(e) Bridge or Router—(f) (mini MAP) End system—(g) End system—(h) Independent LAN's of individual companies—(i) MAP network (mini MAP architecture)

technology for use is mostly created within each company; it has not been established by the industry.

OSI (the open systems interface) is being promoted now as a move toward network standardization. There is organized standardization in Europe and the United States; an OSI promotion group has been established in Japan too, and a relationship of international cooperation has been built up. In particular, MAP has the status of an international standard for factory LAN's; much is expected of MAP as an OSI LAN for FA. FAIS, the development of which has been encouraged by Japan, has similarly attracted international interest as an optical LAN for the lower structure of MAP.

3.1.10 Production Control Systems

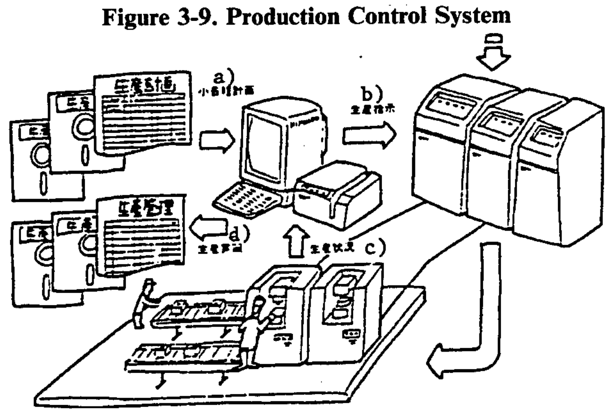
Production control systems are the software that form the core for management of factory production activities, as represented by the MRP (material requirements planning) and JIT (just in time) methods, that are needed to bring about FA. Such software can be obtained as packages from the various computer manufacturers and software houses, but it is often written in-house because codnditions differ from company to company and from factory to factory. For that reason, it has not yet materialized as a market. But because production control systems are an essential technology for FA, there is a strong possibility it will take shape as an independent market.

The future direction of production control systems is expected to shift from distributed processing of production control functions, in the form of systems for use only with FMS in the factory, to high performance production control systems that operate with CAD/CAM/CAE. The appearance of broader production control systems, premised on procurement of parts and materials for the whole enterprise, is also expected.

3.1.11 Connection between FA and Engineering

Attention has been focused on the technology for integrating FA machinery and building new manufacturing systems; that is, on the engineering technology that deals with FA.

Figure 3-9. Production Control System



Key:—(a) Daily plans—(b) Production orders—(c) Production status—(d) Production records

FA engineering deals with systems that comprehend personnel, materials, facilities and machinery. The results of planning, factor procurement, construction and operation under such systems are "a series of activities" which bring about FA in its most appropriate form. The FA engineering industry can be defined as "the industry that provides the activity called FA engineering as the object of correspondences."

Engineering companies were born in Europe and the United States at the end of the 19th century and the beginning of the 20th century. Most of them dealt with continuous (process) plants in the chemical industry.

In regard to FA in scattered plants of the manufacturing industry, it is thought that much of the control technology generated in continuous plants is capable of application in scattered factories, and there are great hopes for FA planning technology as well.

At present, almost all engineering in the FA field is done within the user companies, which are normally big businesses. The engineering market is just taking root; the only market that is evident is that for FA equipment. Companies in such diverse fields as general electrical equipment, machinery, engineering, general construction and distribution are looking into the the possibilities of entering the marketplace as consultants or system integrators.

However, many conditions will have to be met for FA engineering to become established as an industry. That is, the present situation is one of searching out such questions as what kind of risks should be taken, how performance should be evaluated, how to deal with licenses and knowhow, and how engineering fees should be handled. The biggest task for FA engineering companies will be to create the administrative system and climate that is best suited to business in the FA market, a market with great potential.

3.2 The Scale of FA-related Industries

Let us estimate the scale of the FA market in Japan. First, to estimate market scale from the demand side, we will look at the total figure for annual plant investment in various sectors covered by FA. According to the plant investment survey MITI conducted in February 1988, fiscal 1988 plant investment for 1,561 companies in the manufacturing industry came to about ¥13 trillion.

This plant investment included such things as investment in new operations and R&D investment; investment for the purpose of conversion to FA was about 10% of the total. And so, taking into account a capture rate of about 50% for this survey, the market potential for FA industries is considered to be about ¥2 trillion to ¥3 trillion.

To estimate the market from the supply side, on the other hand, the market scale for such major types of FA equipment as NC machine tools, industrial robots and CAD/CAM systems can be estimated at ¥1.6 trillion for 1988. However, that figure does not include FA-related information equipment, software or FA equipment with small markets; if those are given consideration, the FA market as of 1988 can be estimated at ¥2 trillion to ¥3 trillion.

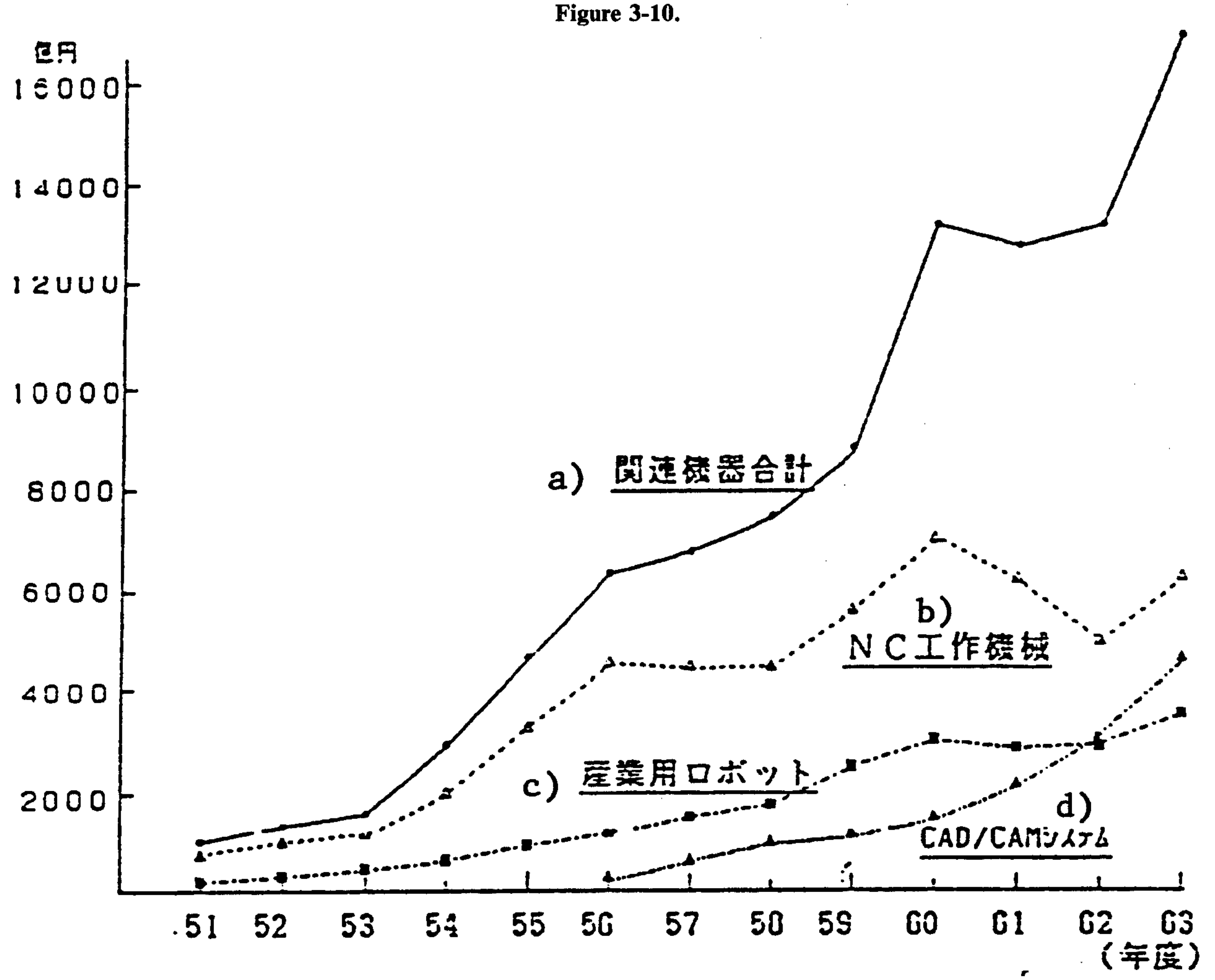
World sales of software and of FA or CIM equipment related to automated manufacturing are estimated at about $42 billion in 1987. It is thought the figure will grow at an annual rate of 9% to 11%, and reach the range of $57 billion to $65 billion in five years.

Figure 3-10.
Production of FA-related Equipment (unit: ¥100 million)

Year	NC Machine Tools	Industrial Robots	Unmanned Transport Vehicles	Automated Warehouses	CAD/CAM Systems/PC's	PC	Operating/Detector Switches	Servo Motors	Total
1976	512	141	—	72	—	—	130	19	874
1977	805	215	—	85	—	—	155	27	1,287
1978	1,076	273	—	69	—	—	169	38	1,625
1979	2,054	424	—	122	—	—	220	69	2,889
1980	3,394	784	—	145	—	—	250	86	4,659
1981	4,340	1,077	—	189	216	—	246	97	6,165
1982	4,217	1,484	—	205	443	—	270	130	6,749
1983	4,266	1,817	—	249	720	—	261	156	7,469
1984	5,899	2,473	—	261	1,104	466	353	253	10,809
1985	7,038	3,001	57	349	1,404	670	351	300	13,170
1986	6,105	2,787	39	369	2,092	633	346	300	12,671
1987	4,860	3,100	71	305	3,159	749	373	541	13,158
1988	6,160	3,600	90	470	4,500	916	460	630	16,826

Source MITI Kikai Tokei Nenpo Japan Industrial Robot Association Japan Distribution Council MITI Kikai Tokei Nenpo Japan Management Association MITI Kikai Tokei Nenpo MITI Kikai Tokei Nenpo MITI Kikai Tokei Nenpo

Figure 3-10.



—a) Production of FA-related Equipment—b) NC Machine Tools—c) Industrial Robots—d) CAD/CAM Systems/PC's

3.3 International Status of Japan and Overseas Activities

FA has come to be actively promoted in Japan's manufacturing industry. Looking at the situation overseas, the situation in the United States is that CIM is generally in the lead, not FA. For the past decade there have been calls for the revitalization of factories and improvement of competitiveness in the manufacturing sector, and CIM has been promoted as the technological direction for that. CIM in the United States can actually be regarded as FA as broadly defined. It is certain, then, that FA is spreading in the U.S. too, but it is characterized there by the emphasis put on computer use and communications networks. Judging from what has been reported, the introduction of CIM has been limited to certain first-rank companies.

CIM is going forward in Europe too. It does not, however, appear to be slanted toward computer use as much as in the United States. The term "FA" is not used, but it seems to be closer to the direction taken in Japan, including its spread to small business. The EC's development plan for manufacturing technology is particularly noteworthy. More than 200 tasks have been set within ESPRIT (European Strategic Program for R&D in Information Technology); the ESPRIT-CIM project is part of the joint development being carried out by companies of the twelve countries of the EC. These projects have the objective of strengthening the competitiveness of European industry. The details of development are spread across a broad variety of projects, and so its real effects will become evident as time passes. Thus there is a strong tendency in Europe to promote the improved competitiveness of the manufacturing sector as national policy.

On the other hand, there has been remarkable recent progress in NIE's like South Korea and Taiwan. The stronger yen Japan has experienced has given the NIE's

more favorable terms of trade with Japan, but the time is past when factories were put in those countries just because of lower personnel costs. They are now able to develop, by themselves, the industrial technology and FA equipment that previously has been introduced from Europe, the United States and Japan; their industrial technology capability is growing steadily. However, the technology for integration will be a major task for the future.

As a matter of national policy in Japan, MITI has conducted development of a mixed manufacturing system using lasers (1977 to 1985) and R&D on FAIS as a part of MAP. So far, development in Japan has focused on hardware—FA-related equipment, and the introduction of FA-related equipment in industry has gone further than in Europe and the United States. It is not possible, however, to predict the future in regard to CIM research and technolological development of the sort seen in projects in Europe and the United States.

4. Tasks and Future Prospects of FA

4.1 Tasks and Future Prospects Environment around FA

4.1.1 Spread and Changing Needs of Information-based Society

Until now the question of human needs has emphasized supplying the basic necessities of life, and the question of industrial production has been a matter of how to efficiently manufacture products in large quantities.

However, the present abundance of society has produced a diversity of values, fostered the movement of women into society, diversification of consumer needs, and individuality. Needs have changed in the direction of individual lifestyles, interests and tastes. In addition to diversification and individualization, there is movement toward cultural and creative activity. In terms of the structure of consumption, the value of Engel's coefficient has dropped greatly, and there has been an increase in "miscellaneous goods," a reflection of diversification.

Figure 4-1. Spending Priorities in 2000 (1981 Delphi Survey)

Category	Young people (under 20)	Old people (over 55)	General population
Dining at home	0	6.7	0
Eating out with family	3.3	3.3	10.0
Life in second home	3.3	20.0	3.3
Beautification of living space	3.3	53.3	36.7
Fashion and finery	90.0	0	16.7
Sports and active leisure	96.7	3.3	46.7
Travel	60.0	60.0	60.0
Theater and performances	20.0	83.3	63.3

Figure 4-1. Spending Priorities in 2000 (1981 Delphi Survey) (Continued)

Category	Young people (under 20)	Old people (over 55)	General population
Cultural attainments of children	0	3.3	3.3
Increased contribution to society	3.3	16.7	6.7
Resource management	0	40.0	13.3

Figure 4-2. Changes in Structure of Consumption (%)

Category	1963	1980	1990	2000
Food	39.7	29.3	25.8	22.2
Housing	9.8	9.5	10.3	11.1
Utilities	3.1	3.9	3.7	3.5
Clothing	12.5	9.3	9.0	8.3
Medical	1.4	2.6	3.0	3.4
Transportation	2.8	7.9	7.9	8.3
Education	11.9	11.3	10.6	10.0
Miscellaneous	18.9	26.3	29.7	33.2

These changes, together with the reduced durability of products, has increased the need for job shop type production that is directly related to the needs of consumers and is capable of producing products that meet those needs, given the reduced lead time for product development and manufacturing.

To adapt to this shortening of product lifecycles, starting from the conventional mode of mass production, it is necessary to change to the new production mode of flexible manufacture of different types of items. Consumption will continue to diversify; this has given rise to the necessity of using FA to encourage adaptation to non-mass production factories that can deal with such things as feedback on consumer needs from the retail shop to the factory.

On the other hand, a response to the diversification of consumer needs only became possible with the spread of the information-oriented society by means of the spread of computers and communications technology. In other words, the development of information processing technology and the conversion of factories to FA made each other possible.

4.1.2 Labor Conditions and Environment of FA

Aside from the demand for FA from the market side, there is also great need for FA on the side of the companies that supply products. According to a MITI questionnaire regarding reasons for carrying out automation and mechanization, the leading reasons are (1) reduction of costs, (2) improvement of productivity and

(3) reduction of labor. Thus, the reduction of production costs by means of FA can be considered a very important task for companies.

**Figure 4-3.
Changes in Employment Structure (%)**

Category	1970	1980	2000
Primary Industries	6.8	2.7	4.0
Secondary Industries			
-Chemicals	11.3	9.0	2.3
-Metals/manufacturing	13.7	11.9	15.7
-Other metals	10.1	8.4	3.6
-Construction	7.4	8.9	10.0
Tertiary Industries			
-Utilities	2.2	3.0	1.2
-Finance/insurance/real estate	12.6	15.5	8.0
-Transportation/communications	6.5	6.6	5.6
-Other services	29.4	33.0	48.6

**Figure 4-4.
Prospects for Industrial Structure (%)**

Category	1970	1980	2000
Primary Industries	6.1	3.7	2.1
Secondary Industries			
-Chemicals	6.4	5.5	3.5
-Primary metals	3.0	3.7	2.1
-Manufacturing	11.3	17.4	28.9
-Other metals	9.9	8.1	5.2
-Construction	9.1	7.6	6.4
Tertiary Industries			
-Utilities	2.2	2.0	1.3
-Finance/insurance/ real estate	11.6	14.3	13.5
-Transportation/com- munications	5.1	5.8	4.2
-Other services	34.4	31.9	32.8
Total (trillion yen)	117.8	188.8	430.0

The major trend in Japan for the past few decades has been a shift of human resources from the primary industries of farming, animal husbandry and fishing to the secondary industries. In recent years, however, industrial structure has continued to change considerably with a further shift to tertiary industries. In the secondary industries, although production has expanded, there has been only a slight increase in employment, because of improved labor productivity, and the secondary industries' share of GNP has declined somewhat. However, the change of employment within the secondary industries has been considerable. The tertiary industries are growing as demand for services continues to grow. By 2000, one of every two employed persons will be employed in a service industry. For that reason, the manufacturing industries have been troubled by a lack of skilled workers, and thus the difficulty of recruiting technicians. There is a chronic shortage of skilled workers and trained workers, and it has become necessary to change job descriptions.

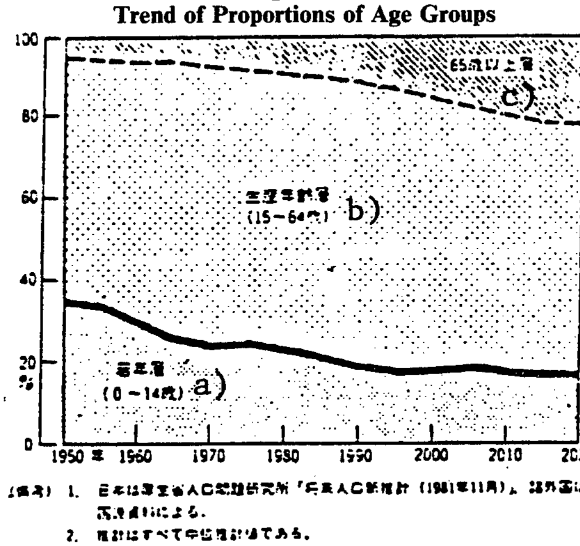
Moreover, there was one older person (65 and above) in 11 in 1980, but in 2000 the figure will be one in 6.4 persons. That will make the shortage of young workers a very real problem in some industries. For that reason, conversion to FA is an essential item in consideration of measures for employment of older persons.

There is also the need for manufacturing systems that give consideration to changes in labor value perceptions and to such factors as improvement of the work environment and job content and the shortening of working hours from the perspective of emphasizing human factors.

The percentage of graduates from institutions of higher learning (universities, junior colleges and technical colleges) in Japan has grown rapidly from 10.3% in 1960 to 37.9% in 1980. Reflecting that, the proportion of persons with higher education wil increase, and the share of such persons within the work force will increase rapidly. Consequently, a major task for the future will be to provide a comfortable, intelligent work environment for this growing layer of workers with higher learning.

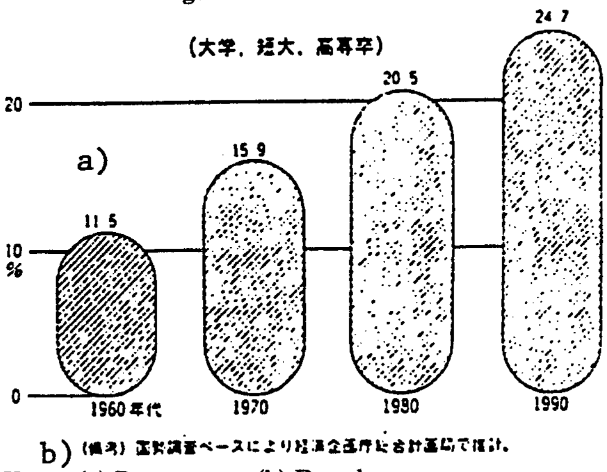
The improvement of working conditions is another merit in the promotion of FA. It provides a release for work in dangerous or harsh environments. Using FA to release humans form work involving high temperature, high humidity, transport of heavy items, loud noise or high places makes it possible to transfer employees who had worked under such conditions to workplaces that

**Figure 4-4.
Trend of Proportions of Age Groups**



Key:—(a) Young (0 to 14 years)—(b) Productive years (15 to 64 years)—(c) Old (65 years and older)

Figure 4-5.
Proportion of Higher School Graduates in Population Aged 20 Years and Above



Key:—(a) Percentage—(b) Decade

demand more intellectual creativity. Moreover, the tediousness of work can be lessened considerably by transferring simple or repetitive jobs to machines. The great appreciation for these positive aspects of FA make up the background for the unresisting acceptance of FA equipment in Japan. In addition, the reduction of working hours is expected to provide a Japanese solution to an international problem. Working hours are gradually being reduced through popularization of the two-day weekend and the increase of paid annual leave.

Figure 4-5.
Proportion of Free Time (%)

Year	Free time	Work, school etc.	Sleep
1970	26.0	40.5	33.5
1975	28.8	37.8	33.4
1980	29.8	36.7	33.5
2000	34	33	33

Note: NHK survey covering persons age 10 and above

Figure 4-6.
Increasingly Popular Two-day Weekend (%)

Year	One-day weekend	Two-day weekend	Other
1970	71.4	17.8	10.8
1975	27.1	69.9	3.0
1980	23.7	74.1	2.1

Note: MOL survey of companies with 30 or more employees. Companies alternating 2-day and 1-day weekends are counted with 2-day weekends.

At the same time, there is concern about the effect on employment of the adoption of FA to meet the great need to save labor. There are reports, however, that it is thought that increased competitiveness through FA will actually increase production and have a positive effect on employment.

Thus, FA has gone forward by substituting machines in jobs that were unpleasant for people. But because the promotion of FA will bring changes in in the demand for different occupations, it will be necessary at the same time to give detailed consideration to those changes so that conversion to FA will progress smoothly. It has thus become necessary to change from traditional, labor-intensive manufacturing to knowledge-intensive manufacturing so that more creative work can be done.

However, at the present time use of FA is far less advanced, in terms of technological capability, financing and human resources, in the small businesses that make up the great majority of workplaces in Japan, than in large enterprises. There is concern, therefore, that these mall businesses will feel a much greater impact from such changes in working conditions and the work environment.

4.1.3 Economic Growth and FA

FA is not just a move toward job shop type production, but also brings labor savings and increased capacity utilization. It also enables improved quality through a reduction of mistakes at work, production of uniform products and increased yield. Progress in expanded sales and reduced costs also brings increased added value produced by company activities. The increase in added value that comes from FA investment and the resultant improvement in productivity will bring benefits that are not restricted just to the enterprises and industries where the investment is made. It will instead be a part of the interaction of economic mechanisms, and there is the possibility that it will expand general demand in a broad range of related industries.

Japan has suffered from a harsh economic climate that has included two oil shocks and sharp increases in the value of the yen. But it has overcome these crises by increasing productivity and the added value of products, and has returned to good economic performance; it is now in the position of a world leader in the economic field.

One cannot ignore, in the background of Japan's economic growth, the labor savings, rationalization and quality improvements that have resulted from FA. It is expected that investment in FA will become increasingly active as the ties between information processing and communications technology become closer and closer.

4.1.4 Internationalization and FA

(1) International Exchange of Technology: It is necessary that Japan, which leads the world in manufacturing technology, respond to requests from the NIR's and developing countries for training of human resources

and technological cooperation on manufacturing systems. At present, however, there is a shortage of institutions to accept such requests; it is desirable that institutions to accept trainees be established, as well as training institutions to send FA technology abroad.

Greater technological cooperation with Europe and the United States is also desired. Japan will be expected to make an increasing contribution in the international arena, including active encouragement of international standardization of FA and promotion of joint development of technology. Forums for exchange of technology can be expected to expand; there has been inadequate planning of and participation in international conferences, symposiums and research institutions to carry out an active exchange of manufacturing system researchers.

(2) Overseas Development of Manufacturing Industries: So far there has been an active extension of the manufacturing sector overseas, particularly to Asian countries, because of the steep rise of personnel costs in Japan. Local production in Europe and the United States has been encouraged in recent years in order to deal with the growth of exports, the intensification of trade friction, changes in foreign exchange markets and the trend toward bloc economies.

Figure 4-7.
Direct Overseas Investment ($100 million)

Fiscal Year	Manufacturing Industries	Nonmanufacturing Industries	All Industries
1981	23.1	66.3	89.3
1982	20.8	56.3	77.0
1983	25.9	55.6	81.5
1984	25.1	76.5	101.6
1985	23.5	98.7	122.2
1986	38.1	185.1	223.2
1987	78.3	255.3	333.6
1988	138.0	332.2	470.2

When one operates an overseas manufacturing base, it is often the case that the Japanese style of manufacturing is not really appropriate, because of the different culture and customs of the host country, including the level of its personnel resources, its religion and its lifestyle.

For that reason, it is necessary to establish base models of FA systems to be used in foreign countries, and it is important to collect information and be fully conversant with the labor and cultural situations overseas. The expansion of overseas manufacturing bases will also make an international network necessary to connect the bases to the headquarters organization. The globalization of companies will go forward by means of these international information networks that include overseas manufacturing bases.

The rise of the NIE countries, on the other hand, will accelerate a shift of industrial products in Japan to higher value-added products.

In the future, increasing numbers of smaller companies will expand overseas along with the large companies; it has become necessary to consider what to do about these smaller companies.

4.2 Tasks and Prospects of FA Technology

4.2.1 FA Hardware Technology

Japanese FA equipment is in the top class in the world market, in terms of both quality and cost. It cannot be said, however, that factor technology development is adequate yet to meet the demands for higher performance, including greater precision and faster equipment. Moreover, There are major tasks in terms of FA peripheral technology, in that AI and sensor technology is not yet mature, and there are limits to the use of robots.

It is difficult to say that individual pieces of FA equipment can be easily combined into systems. Moreover, there are inadequacies in terms of equipment communication protocols, languages (for robots and PC's), man-machine information processing and wide-area control of information, and a great deal of effort is necessary in system creation and maintenance.

Therefore, further development of technology in Japan will remain desirable.

Trends in development of FA-related equipment can be listed, by field, as follows:

(1) Machining

- development of processing equipment to process parts produced by high-precision plastic deformation using new materials
- development of technology to machine new materials such as ceramics
- development of high-speed (kilometers per minute) cutting and grinding technology
- development of precision machining technology with a surface precision of .01 micron
- maintenance of shape precision of 1 micron in gutting of general machine parts

(2) Robots

- development of repair robots and other mobile robots
- use of robots for unmanned operations in harsh environments
- development of high-speed robots and distribution equipment
- determination of position at the micron level of precision
- inclusion of AI functions

(3) Sensors and Instrumentation

- development of sensors with more nearly human perception
- spread of instrumentation systems that use light for extreme precision

(4) Control and Information

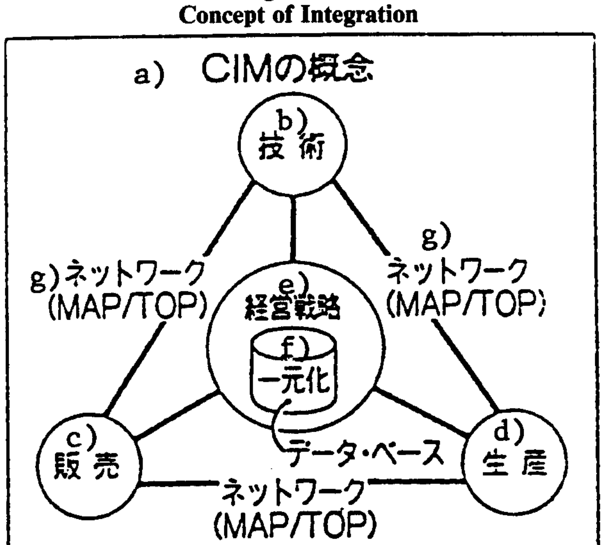
- development of high-speed, high-capacity information equipment
- development of automatic recovery function that uses self-diagnosis and automatic problem solving
- development of FA equipment and systems with a fail-safe function
- development of flexible, automatic test equipment
- high-speed, high-capacity communications, standardization of protocols and conversion to open systems
- improved performance and standardization of man-machine interfaces
- standardization for data interchange among CAD/CAM/CAE systems

4.2.2 FA System Technology

(1) System Integration Technology: With such social changes as the diversification of the needs of consumers in relation to manufacturing systems in the industry today, it has become necessary to build manufacturing systems that organically link manufacturers, researchers and consumers.

That is, FA will extend in many directions, the information of the manufacturing company as a whole will be integrated by means of systemizing manufacturing sites, streamlining the administrative sector by conversion to information processing, and streamling distribution, and networks with other industries will be formed. Thus, the demands for integration will become more and more complex, and higher in level. Consequently, integration of a well-balanced system is important for creation of an

Figure 4-8.
Concept of Integration



Key:—(a) Concept of CIM—(b) Technology—(c) Sales—(d) Manufacturing—(e) Management strategy—(f) Unified databases—(g) Network (MAP/TOP)

FA system. The preparation of technology and training of personnel for network integration will continue to move forward.

In the construction of such information systems, the more advanced networking becomes, the more necessary it will be to give full consideration to the problem of security.

(2) FA Evaluation Technology: With regard to methods of evaluating FA, so far research has only begun at the FMC and FMS level. However, there are many uncertain factors in the effect of introduction of FA, and no general, persuasive design methods have been established for design of FA systems; design is usually dependent on the effort and the experience of the designer. Construction of FA systems is dealt with one at a time, and invites redundant development; it certainly does not rate highly in terms of productivity, and limited human resources in the FA field are not used effectively.

For that reason, it will be necessary to establish pertinent standards for evaluation, and means of quantitative measurement for use in the design, introduction and operation of increasingly complex FA systems.

Development of evaluation methods with a high level of common characteristics is particularly essential in the establishment of an FA system integration industry.

(3) Standardization: The preparation of norms and standards for building FA systems is important to the promotion of integration. The creation of norms and standards is essential to the conversion of industry to FA. Use of norms and standards will make it possible to standardize the data flowing within or between factories, establish networks connecting a number of different businesses, standardize communication protocols (centered on MAP), and control a company's production information on-line.

On the other hand, creation of such norms and standards will enable various manufacturers to develop FA equipment, FA networks and FA system software in accordance with the standards, and these will be interoperable. In that way, the system integrators who build these systems will emerge as a new industry.

The establishment and standardization of software architecture for CIM as a whole will also be carried out. Generalization of logic for writing applications and technology for databases, will be important, as will technology for automatic generation of application programs.

(4) Application of New Technologies: Control systems that introduce new ideas like AI and fuzzy logic will emerge during the creation and operation of systems. In addition, systems for simulation of manufacturing will be enhanced, and will be capable of real-time use.

4.3 Tasks and Prospects of the FA Industry

4.3.1 The FA Hardware Industry

At present, almost all FA equipment is built with emphasis on individual automation; few products are oriented toward total systems. That is, little thought is

given to interoperability even of products from the same manufacturer, much less products of different manufacturers. Consequently, systemization of FA is obstructed by inadequate interoperability and substitutibility of FA equipment.

That being the case, future systemization of FA will require promotion of the standardization of equipment. On the other hand, it is necessary to maintain competition among companies by preparing a framework for development and supply of equipment suited to the individuality of user companies. For that reason, it is often the case that FA equipment is turned to single item manufacturing with much work outside the factory, such as on-site adjustments, and uncompensated engineering work is often required.

The FA equipment industry is an important, basic industry that supports plant investment; it is also a high-technology industry that requires huge R&D expenditures and many researchers. But because the size of individual markets and companies is not all that large, there has been a lag in its development of basic technology.

To forecast the trend of the FA equipment market in 2000, the materials of various industrial associations say the market will be from ¥800 million to ¥1 trillion in domestic demand for machine tools, ¥1.27 to ¥1.5 trillion for industrial robots (three to four times the 1988 level). If one considers information processing equipment as well, the market for minicomputers is expected to reach ¥700 billion (about three times the 1988 level). Extrapolating from those figures, the FA equipment industry can be expected to grow from the present ¥2 to ¥3 billion to about ¥5 trillion in 2000.

[ ] 4.3.2 The FA System Industry

Compared with the past concept of FA, which consists primarily of the automation of individual tools or subsystems (such as FMC), in recent years the major task has come to be integration with information systems, as seen in the CIM concept. Carrying out this integration of systems involves a number of tasks, including connection of sybsystems in a multivendor environment, establishment of network architectures and internal data unification. Other obstructions to promotion of FA are the shortage of engineers and the lack of technical information. For those reasons, it is thought, there has been a tendency to contract with system integrators outside the company. In order to succeed, these system integrators have to solve the following problems.

That is, as system integrators who bring everything together, they must fill these conditions:

(1) Increased capability for comprehensive engineeering of CAE, CAD, CAM and CAT (computer-aided testing)

(2) Required payment of FA engineering fees

(3) Assurance of rich experience and broad knowledge

(4) Cultivation of comprehensive consulting capability that can make a direct contribution to management strategy that gives integrated consideration to administration, business management, plant management, production management and personnel management

(5) Enhanced capability to bear risk for integration of the total system

(6) Acquisition of knowhow and trade secrets

(7) Provision of technology and facilities for system maintenance

As FA has incorporated concepts like CIM and becomes increasingly integrated and complicated, it has become increasingly difficult for each company to keep large numbers of specialized technical personnel. Looking at it from the supply side, there has also been a tendency to sell equipment as systems, with the higher added value. And there have been moves to order such whole FA systems; software houses that perform specialized integration of FA subsystems and an industry that builds information and communications networks have begun to appear.

4.4 Tasks and Prospects of FA in the Manufacturing Industries

4.4.1 Tasks and Prospects of FA Implementation

A number of problems have arisen that should be solved as manufacturing industries implement FA.

First, There is the big problem of obtaining human resources to design and implement FA. Carefully considered FA systems have not been introduced because of the shortage of leaders to encourage FA and of technical personnel to oversee the FA system as a whole. Present FA systems are company-specific systems that clearly express the special characteristics of the company. Great effort at integration is needed; it can hardly be said that FA systems are working as originally hoped

Moreover, the imbalance between processes that arises from special features of the production equipment and the work performed can make effective use of facilities difficult, and may keep the system from achieving its original objectives, making it unacceptable within the company. In the fiace of such a situation, systematization will require a great deal of time for planning, introduction and promotion. The situation is not favorable for encouragement of FA if there are not strong promoters in the company (in top management, for top-down efforts), if the company's work has not been standardized for the introduction and operation of FA, or if there is weakness in the horizontal management of a number of departments related to FA (especially in a company with a highly segmented organization).

On the other hand, even when an FA system has been constructed, there are still problems of staff education and training, including changes in the work performed

by maintenance personnel and improvement of jobs that cannot be completely automated.

The increased complexity and scale of FA systems in recent years has increased the amounts to be invested, and have made it important to plan a step-by-step introduction of FA for continuity of manpower and capital; it has become necessary to carefully evaluate the effectiveness of FA investment. However, the advance of multistage processing has made methods for evaluating the introduction of systems increasingly ambiguous, which has made decisive investment difficult.

Demands on FA systems to be introduced are expanding, including the automatic assembly of very light and very heavy products, but have not been fully satisfied. There are still many technical problems to be solved.

This being the situation, FA has been introduced in the face of high personnel costs and personnel shortages in the initial stages. But hereafter, as Japanese industry shifts to products with higher added value, there will be an increasing orientation toward automated and unmanned creative and developmental activity, rather than toward human resources.

Moreover, the needs of consumers will continue to diversify. As the technological revolution accelerates, quick comprehension of consumer needs and reduction of lead-time for development and production of products will be major tasks. The preparation of manufacturing industry information networks is indispensable for that purpose.

4.4.2 Tasks and Prospects of FA Implementation in Small Business

A large proportion of small businesses are companies that supply parts as subcontractors to large companies. These subcontractors differ from large companies both in their scale of operations and the nature of their products, so it will not always be possible to apply FA technology established in large companies directly to small companies without adapting it; FA models for small companies are needed.

Because of changes in the economic climate, parts procurement is shifting overseas and manufacturing bases are being transferred abroad. For small firms to survive in such a situation, they must become able to manufacture products of higher quality, with higher added value, in a shorter time. In an environment where the amnufacturing industry as a whole suffers from personnel shortages, the problem is all the more serious in small business. That makes it essential to introduce FA systems that can raise productivity with small numbers of personnel.

Thus, the promotion of FA will be necessary in small businesses too, but it cannot be denied that they will have less technological capability than large companies for either planning or operating FA systems. The inhouse training of FA technicians that is possible in large companies is difficult in small firms because of the problems of the potential of present workers, training opportunities and surplus energy. Use of existing personnel for systemization is extremely difficult, and the great investment necessary for FA is another big problem for small firms.

While big companies are actively encouraging FA, small firms have shortages of both capital and personnel. They may become polarized into companies that will gamble their survival on FA investment and those that will not.

Small firms that go ahead with FA will need systems that can receive on-line, real-time, standardized data from purchasers, and respond to those orders by producing and shipping products with minimum lead times. The introduction of interoperable FA systems that use standardized equipment is indispensable to meet that need.

If there were industry-standardized hardware and software for FA system sat this time, it would be possible to order various types of equipment from a variety of companies, and the independence of small companies could be established. But if the makeup of FA systems is subordinate to specific large companies, the systems and related information may be controlled by those large companies.

Because smaller firms will continue to lack technical personnel to design FA systems, it will usually be necessary to rely on system integrators. Another direction would be to have products that do not face competition, based on special technology or in fields FA cannot deal with.

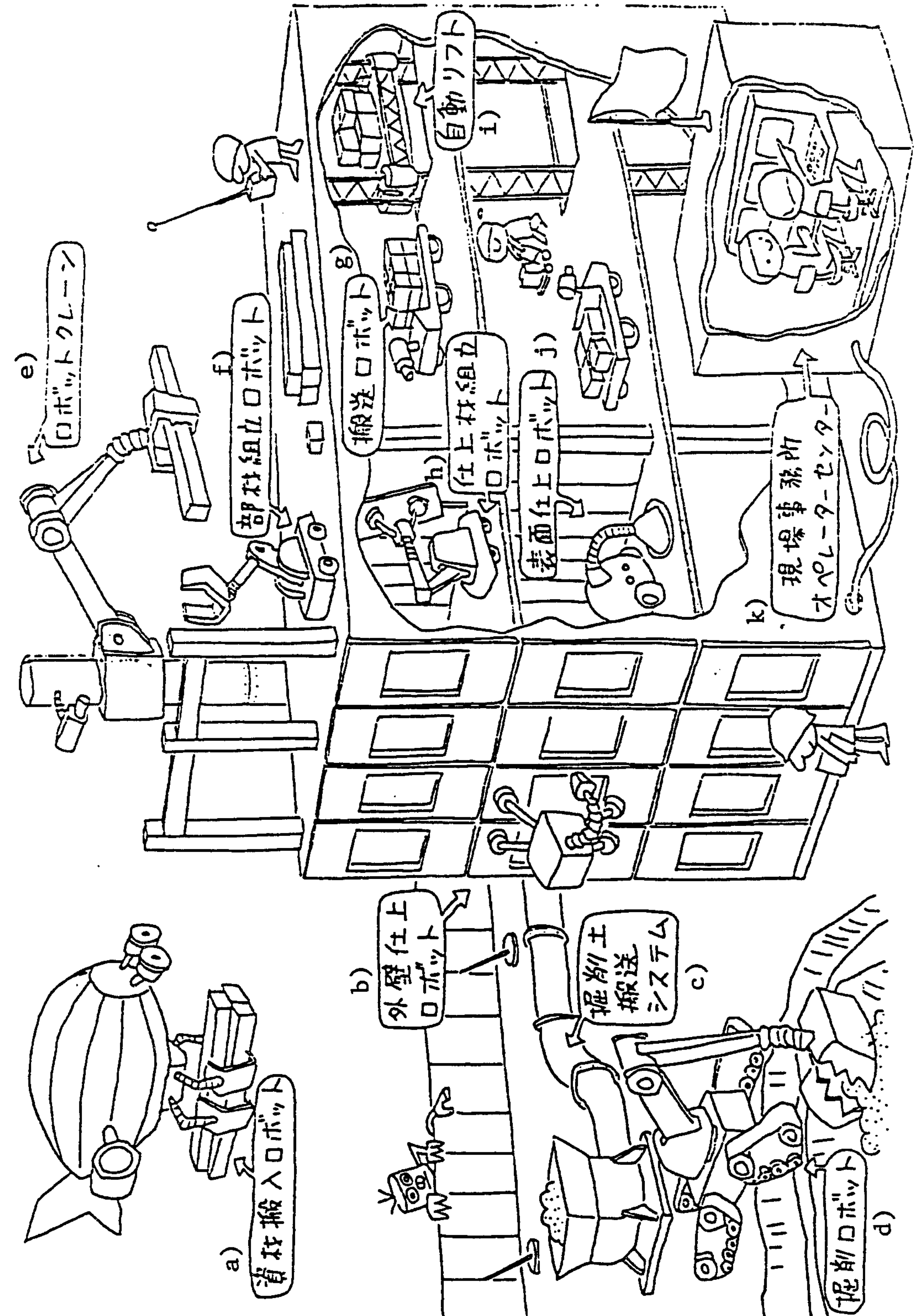
4.5 Directions of FA in Nonmanufacturing Industries

The automation occasioned by progress in microelectronics in recent years began in such secondary industries as machining and assembly, but recently it has expanded to other industries including botanical production, food processing and marine products; it is developing toward rationalization of all industries, including agriculture, fisheries, distribution and construction (see figure 4-10).

As can be seen from the robots developed for the manufacturing industry, it will be possible to use FA equipment and software in various industries, and the FA equipment industry will become even more active. Labor savings and improved productivity will be inevitable even in the tertiary, labor-intensive service industry. At that time, streamlining will go forward using the idea of FA.

But judging from the manufacturing industry, it will not be possible to just use FA conceived for factories in the future when needs are diversified and product life is shortened. Implementation must be done broadly, in connection with the external service industry. and the importance of systems like POS (point of sales) will increase. Systems that are consistently automated from

Figure 4-10. FA in Building Construction



Key:—(a) Material transport robot—(b) Outside finish robot—(c) Excavated soil removal system—(d) Excavation robot—(e) Robot crane—(f) Parts assembly robot—(g) Transport robot—(h) Finish materials assembly robot—(i) Automatic elevator—(j) Surface finish robot—(k) Work site office and operator center

production through distribution may be introduced in fields like fashion and publishing where there are direct ties to the consumer.

5. Proposals

5.1 Introduction of New Term

This discussion group originally defined FA not just as factory automation, but as a concept that included automation and integration of all company activity. But because it has been pointed out that the existing terms FA and CIM do not accurately express Japanese manufacturing technology, our proposals will include a call for a new term.

As represented by terms like TQC (total quality control), companies in Japan ares supported by bottom-up production activity at all levels, from management through design, manufacturing and service. We propose the term IMS (intelligent manufacturing system) for a system that takes advantage of intelligent activity at all those levels, fuses the activity of machines and people, and integrates the manufacturing activity of the manufacturing industry as a whole.

5.2 Contribution to Internationalization

5.2.1 Promotion of IMS Technology Exchange

(1) Background and Necessity: Japan's manufacturing technology was acquired from Europe and the United States after the war, and accumulated by the private sector in a bottom-up fashion; it has come to lead the world. As a result of the great leap of productive capacity that Japanese industry has made in the course of that, strife represented by trade friction has arisen between Japan and foreign countries. For that reason, Japan will want to combine competition with cooperation and make an international contribution in the field of technology, in order to play a positive role as a member of the international community. Although an exchange of researchers is conducted now at the governmental level, much of the manufacturing technology foreign countries want has been accumulated within private companies. An active exchange within the private sector is desirable to spread this technology properly within the international community.

(2) Direction of Response: The information and technology of individual companies is often what foreign countries really want. But because it is difficult to systematize that information and technology and put it into manuals, the technology is difficult to spread. Consequently, it is necessary for both the government and the private sector to make every effort to systematize IMS technology and spread it broadly through the world as a community asset. Basic IMS technology developed by the state will be the focus, but IMS technology held by companies should also be spread, on the basis of economic principles.

It will also be necessary to conduct joint R&D, primarily in Japan, Europe and the United States, on the FA equipment technology and system technology that will dominate future IMS technology, and to conduct technology exchanges, focused on the transfer of appropriate technology, with the NIE's and developing countries.

To spread Japan's technology broadly through the world, it will be necessary to actively encourage technology exchanges, to plan and host symposiums and international conferences in accordance with Japan's leading position, and to participate in international conferences convened by other countries.

It will also be necessary to give careful consideration to the handling of intellectual property rights involving manufacturing technology.

5.2.2 Active Contribution to ISO and Other Standardization Bodies

(1) Background and Necessity: Till now, Japan's approach to bodies like ISO (International Organization for Standardization) and IEC (International Electrotechnical Commission) has been one of considering proposals made by other countries. As is shown in figure 5-1, the proportion of executives drawn from Japan, with its high industrial manufacturing capability, is certainly not large, even considering regional distribution and the language problem. Thus there is the aspect that Japanese views are not always easily reflected in standards.

Figure 5-1. Origins of ISO Executives (Technical Committees, Subcommittees and Working Groups)

Country	Number
Britain	404
West Germany	410
France	375
Netherlands	69
Italy	64
Other EC	64
Sweden	107
Other Western Europe	102
United States	294
Canada	101
Soviet Union	55
Other Eastern Europe	35
Japan	45
Asia and Middle East	37
Oceania	34
Africa	10
Latin America	3
Designated	150
Total	2359

It is desirable that Japan make a contribution by participating more actively and having its proposals reflected in activity to set international standards, and by actively presenting Japanese successes in fields where it holds technological superiority.

(2) Direction of Response: We will participate actively in organizations like the ISO, and particularly its current TC184 (Industrial Automation Systems), and we will take the approach of making proposals.

To do that, it will be necessary to encourage active participation by the private sector, in order to draft the standards Japan is to propose.

5.3 Fostering IMS Technical Personnel

5.3.1 Augmenting IMS Technical Training

(1) Background and Necessity: It is widely recognized, within Japan and abroad, that the conversion of the manufacturing industry to IMS is essential to the future development of the manufacturing industry. However, IMS technology is a comprehensive technology that cuts across a broad range of manufacturing technologies; it is a region of technology not dealt with in conventional, vertically divided fields.

In the United States, manufacturing technology education has come to be offered in universities as a field of industrial engineering. In some community colleges (funded by states, the federal government or businesses), training in CIM-related technology is given to students or company employees; the number of students has reached 27,000. In Japan, on the other hand, there are hardly any schools with courses related to IMS.

At present, companies have very few technical personnel capable of building IMS systems, and in small companies there are next to none. The training of such IMS technical personnel will require the systematization of IMS technology. And because there are limits to IMS training inindividual companies, it will have to go forward in an academic setting that lacks experience with increasingly diverse and complex IMS technology.

(2) Direction of Response: Traditional college education is based on individual specialized courses, but the recent tide of systematization is changing to a current of demand for personnel with complex technical capabilities. Consequently, there is great desire for preparation of an attractive training arrangement that can acquire IMS integration technology and recruit talented sudents, so as to provide useful personnel for the industry of Japan and the whole world.

5.3.2 Fostering Technical Personnel

(1) Background and Necessity: The appearance of facilities in the manufacturing industry has changed greatly with the latest advances in microelectronics. The change of technology has not just improved productivity in the manufacturing industry, but has improved the work environment and contributed to creating a climate that is easier to work in. This has generated the necessity for employees in the manufacturing industry to learn to use the new facilities. Beyond that, the content of work will have to change because of changes in the social climate, including the shortage of personnel in the manufacturing industry, the aging of society and incursions by women.

A conversion to IMS, which will provide a better work environment and jobs with a sense of accomplishment, is an important matter for consideration by a manufacturing industry that is having increasing trouble recruiting workers. And training of workers that can cope with this progress in IMS technology is an important matter for Japan in securing human resources and capital.

(2) Direction of Response: The recent wave of technological innovation has spread to factories and offices, and has made the acquisition and application of new technology necessary for factory technical personnel and office employees. It is thus necessary to consider forums for the training and retraining of technical personnel.

5.4 Easing Introduction of IMS in Small Business

(1) Background and Necessity: The environment in which Japan's manufacturing industry exists is faced with a major period of transition that involves higher educational achievement and an aging population, a stronger yen and overseas production sites, and diversifying consumer needs. Industry in Japan has developed through cooperation between large companies and smaller companies, but now these changes threaten to weaken the smaller companies, which support Japan's manufacturing industry, through the departure of workers and the withdrawal of managers from the manufacturing industry, and that could cause the hollowing out of the manufacturing industry, To avoid that, it will be necessary to affirm the role of small businesses in Japan, and to support IMS in the capital, technology and personnel aspects to achieve sound growth.

(2) Direction of Response: We should draft guidelines on the introduction of IMS in in smaller companies that support Japan's manufacturing industry, and implement measures to give technical guidance and measure and diagnose the effects of IMS. We should also actively encourage IMS through tax and financing measures to facilitate its introduction.

5.5 Encouraging Development of IMS Technology

5.5.1 Development of IMS Architecture and Integration Technology

(1) Background and Necessity: Japan, which leads the world in the field of manufacturing technology, is actively pursuing IMS-related technology through research on technology for individual pieces of IMS equipment carried out in industry and in research institutions. But although some companies and research institutions have done research on establishment of the architecture that forms the concept of IMS systems, on

basic IMS software that will be the core of its structure, or on the planning and evaluation methods that will provide direction during design and construction, the process is barely started. Consequently, the construction of IMS systems will often depend strictly on current experience, human resources will be wasted, and long-term objectives will not be achieved. Moreover, in the ever-increasing technological exchanges with other countries, there will be times when Japan's "superior" manufacturing technology cannot fully respond to the requests of other countries for a smooth transfer of technology because systematization of the technology has been delayed.

For Japan to play a leading role in IMS technology, it is essential that the required basic technology be established five or ten years in advance. This basic technology of IMS cannot be established in a single company, but must be thought of as a social asset developed at Japanese initiative. This is a field in which other countries expect much of Japan, with all its economic and technological power.

It is therefore necessary that Japan take the lead in R&D on IMS technology, and make an active contribution to it as a social asset of the manufacturing industry of the world.

(2) Direction of Response: We will make an international contribution to the problem of basic technology to create IMS, by developing it as a social asset and by popularizing IMS technology.

Consequently, it is necessary to bring together the full efforts of industry, government and academia to begin the development of IMS structure and integration technology. The following three points will be important as specific tasks at that time:

- development of IMS architecture
- development of basic software (operating systems, databases, languages etc.) that will facilitate the construction of IMS systems and provide desired functions
- development of IMS planning and evaluation methods

5.5.2 Encouraging Standardization of IMS Hardware and Systems

(1) Background and Necessity: A great deal of equipment for IMS systems is being developed and marketed in Japan now. But because of the strategies of each manufacturer to distinguish its products, the popularization of products is spotty, interoperability is poor and the integration of IMS systems is greatly hindered.

On the other hand, the wave of increased use of information has reached the manufacturing industry, and the integration of IMS systems as represented by the term CIM has become the primary mission of the manufacturing industry now. Because it is not possible to freely connect this equipment under current circumstances, users have no choice but to attach special adapters or use complex systems.

The encouragement of standards that unite the hardware and software aspects of the technological development of IMS equipment will be essential to promote the integration of IMS systems in Japan. Japan has been asked to show international leadership in regard to IMS; it would be impermissible to just passively accept the accomplishments of others in international standardization activity as represented by the promotion of MAP/TOP. It is therefore important that Japan actively engage in the development of standards in cooperation with other countries, as in the case of the FAIS (factory automation interconnection system) project the government is carrying out now.

(2) Direction of Response: The international standardization of IMS equipment is essential, not just for Japan but for the whole world. It is necessary that Japan, which is in the position of a world leader in the IMS field, promote hardware and software standardization (including communication protocols, man-machine interfaces, IMS languages, robot languages, IMS databases, unification of data for the manufacturing industry, CAD (tests of the compatibility of systems and data) and operating procedures for IMS equipment) to enable easy interconnection of IMS equipment, and that it promote standardization of system structure.

5.5.3 Study of Human Interfaces in an IMS Environment

(1) Background and Necessity: As the activity of the manufacturing industry becomes increasingly complex, companies are moving in the direction of automation with the introduction of IMS, but complete automation is not necessary. This will always be an important factor in the relationship between manufacturing activity and people, but from the perspective of people and IMS or man and machine, adequate study has not yet been given to the effect people and IMS will have on the interrelationship. There are few examples in Japan of systems or machines that have been examined from the perspective of human engineering; the methods of using these machines is generally called complex. Considering the acquisition of human resources and internationalization, the aging of society and employment of women, it will be necessary to give full consideration to the human interface with equipment.

(2) Direction of Response: It is necessary to clarify what effect the IMS environment will have on people, and it is necessary for industry, government and academia to consider the methodology for building systems that are optimum for both people and IMS.

5.5.4 Promotion of IMS Technology Internationalization Program

(1) Background and Necessity: Starting with the flexible automation of the factory, IMS has the objective of

integrating all manufacturing activity and improving productivity. It is widely recognized, in Japan and abroad, that this IMS is essential to the development of the next generation of the machine industry. For that reason, we should actively promote R&D on next-generation IMS technology.

To achieve internationalization, which is a future task for Japan, conducting international joint research with the advanced countries of Europe and the United States and transfering the resulting technology to NIE's and developing countries is an urgent matter. Implementing programs from an unprecedented new perspective is similarly an urgent matter in order for Japan's manufacturing industry to develop harmoniously on an international and long-term basis.

In order to implement international joint research in a program, it is necessary to have a mutually cooperative research arrangement to which Japan, the United States and Europe all bring their fields of particular interest. That is one method for making IMS succeed.

It is also necessary to give consideration to NIE's and developing countries by means ranging from technology transfer for machine systems (at the FMS level), suited to the level of their industries, through internationalization.

Creation of a truly effective IMS is impossible without technology for optimal system integration; commencement of large-scale R&D is an urgent task. Therefore, we will carry out R&D on technology for creation of IMS integration systems.

IMS technology is an integrated, international technology that comprehends a broaud range of manufacturing activity. Because it is difficult to deal with that broad scope using conventional, vertically-divided fields of technology, it is important to gather a broad range of human resources and conduct research efficiently. It is therefore essential to adopt a program formula in which the projects are carried out as a group.

(2) Direction of Response: We will conduct R&D on technology for creation of IMS intgrated systems that will integrate, into a system that is optimal for the user, a diversity of manufacturing functions ranging from planning and management of manufacturing through machining and assembly.

Specific targets of projects to be studied include integration technology, management and optimization measures, system evaluation measures, testing environments, and development of test and inspection systems.

6. "Status of FA" Survey and Analysis

6.1 Outline of Survey

This survey was conducted in May 1989 by MITI's Machinery and Information Industries Bureau [MIIB] as data to back up the "Long-term Prospects for FA" drafted in the FA Vision Discussion Group, a personal advisory body of MIIB's Director General. A questionnaire was sent to companies in the manufacturing industry (95 representative large companies, and 78 smaller companies). Replies were received from 70 large companies (74%) and 51 small companies (65%) and the results were analyzed.

The large companies were selected to be representative of the various sectors of the manufacturing industry. The small companies were selected from those having at least 100 but no more than 1,000 employees.

6.2 Survey Results

6.2.1 Company Responses

1) Breakdown of companies responding: The large and small companies involved in this survey are classified by capital, number of employees, production and sector as shown in figures 6-1 through 6-4.

Figure 6-1.
Capital (unit=¥ 100 million)

Range	Percentage
Large companies (69 responses)	
1 to 10	1.4
10 to 50	4.3
50 to 100	10.1
100 to 500	44.9
500 plus	39.1
Small companies (51 responses)	
Less than 1	17.6
1 to 10	68.6
10 to 50	11.8
50 to 100	2.0

Figure 6-2.
Employees

Range	Percentage
Large companies (69 responses)	
1,000 to 10,000	58.0
10,000 plus	42.0
Small companies (51 responses)	
Less than 300	47.1
300 to 500	29.4
500 to 1,000	21.6
1,000 to 10,000	2.0

Figure 6-3.
Total Production

Range	Percentage
Large companies (69 responses)	
30 to 50 billion	4.3

Figure 6-3.
Total Production (Continued)

Range	Percentage
50 to 100 billion	11.6
100 to 300 billion	33.3
300 to 500 billion	10.1
500 billion to 1 trillion	21.7
More than 1 trillion	18.8
Small companies (51 responses)	
Less than 5 billion	31.4
5 to 10 billion	35.3
10 to 30 billion	25.5
30 to 50 billion	7.8

Figure 6-4.
Sector (unit=1 company)

Sector	Large companies	Small companies
Foods	3	1
Textiles	3	—
Paper and pulp	—	—
Chemicals	—	1
Pharmaceuticals	2	—
Miscellaneous chemicals	4	1
Oil and coal products	—	—
Rubber products	1	—
Kiln products	1	—
Iron and steel	2	—
Nonferrous metals	4	—
Metal products	3	9
Machinery	11	13
Electric machines	15	14
Precision equipment	7	4
Automobiles	6	3
Other transport equipment	3	1
Miscellaneous manufacturing	3	4

2) Plant investment: Plant investment was queried for the past three years, the plan for 1989, and the next three years. FA investment was also checked.

As for the amounts invested, with the background of a flourishing expansion of domestic demand, both large and smaller companies planned greater plant investment than in the past three years. The plant envestment planned for the coming three years was slightly greater than that of the past three years, but it does not appear that plant investment will continue at the level of this fiscal year.

What part of plant investment is FA related depends on the definition of FA, but the proportion is tending to increase, to over 10% in large companies and 20% to 30% in smaller companies. The reason for the difference between large and smaller companies is thought to be that in smal companies in the manufacturing industry, most investment contributes directly to production. (Past and future figures are averages for the three year periods.)

3) Composition of employees: Composition of the employees is shown at intervals of approximately 10 years. This shows that 30 years ago there was a high proportion of employees directly involved in production in both large and smaller companies, a labor-intensive situation. In large companies, where automation and rationalization are in progress, the direct production proportion is expected to drop from 57% in 1960 to 35% in 2000.

Labor savings have not gone as far as expected in smaller companies; unlike large companies, they tend to be labor intensive even now. However, a trend toward labor savings will appear in the next ten years.

4) Response to upgraded production methods: Orientation toward upgraded production methods (FA, CIM) is high in both large companies and smaller companies. But while they have been implemented in about 86% of large companies, only 47% of small companies have implemented such methods. It is clear that the rate of implementation will be even lower in the smallest companies. It is thought that FA in small business will progress with the future tendency of improved performance.

On the other hand, a large proportion of both large and small companies cite, (1) diversification of products, (2) shortening of lead time and (3) integration of manufacturing by computers as reasons for implemented upgraded manufacturing methods.

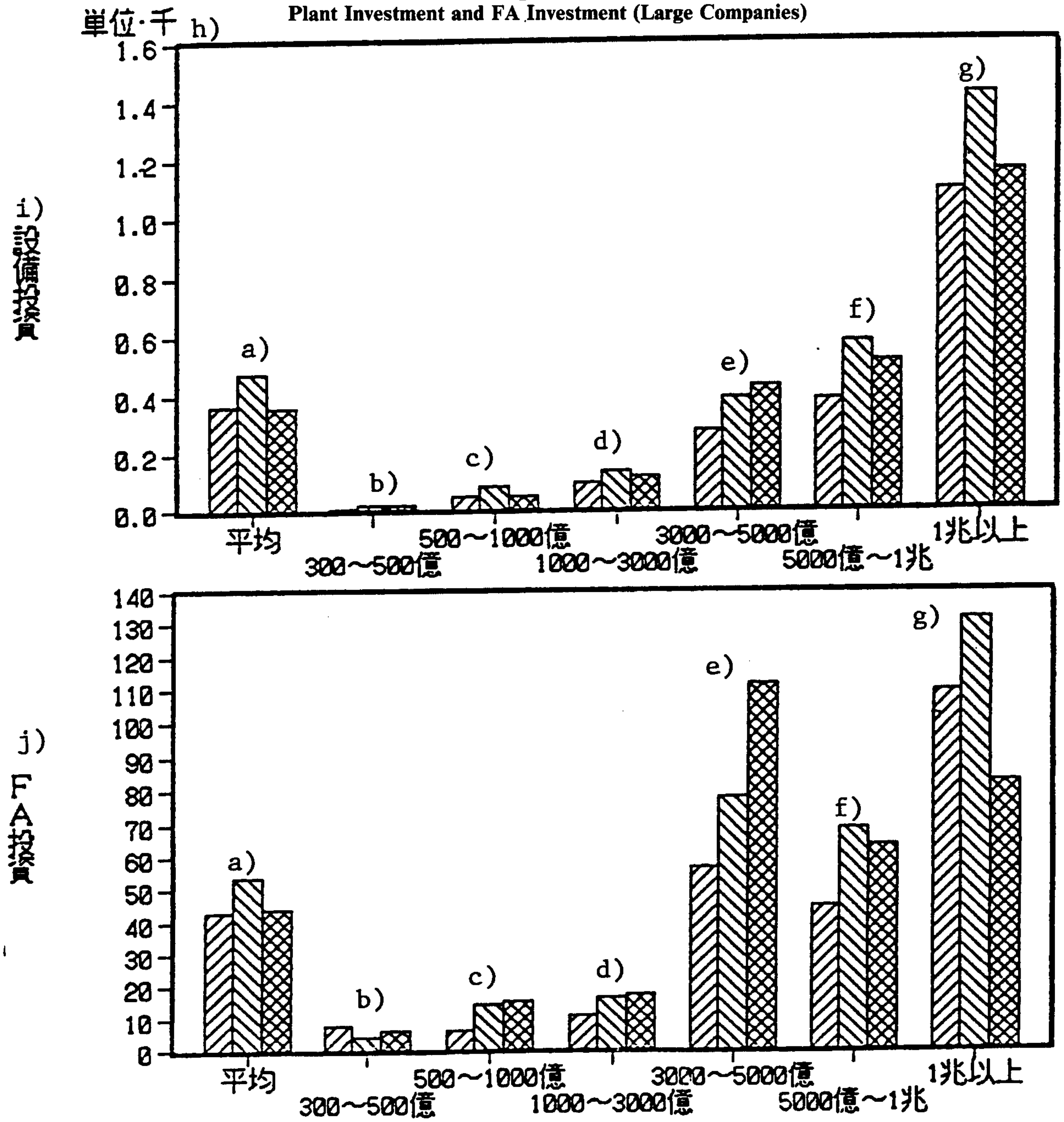
Figure 6-10.
Plans to Upgrade Manufacturing Methods

	Large companies (67)	Small companies (51)
Have plans	97.0%	80.4%
No plans	3.0%	19.6%

Figure 6-11.
Implementation of Upgraded Manufacturing Methods

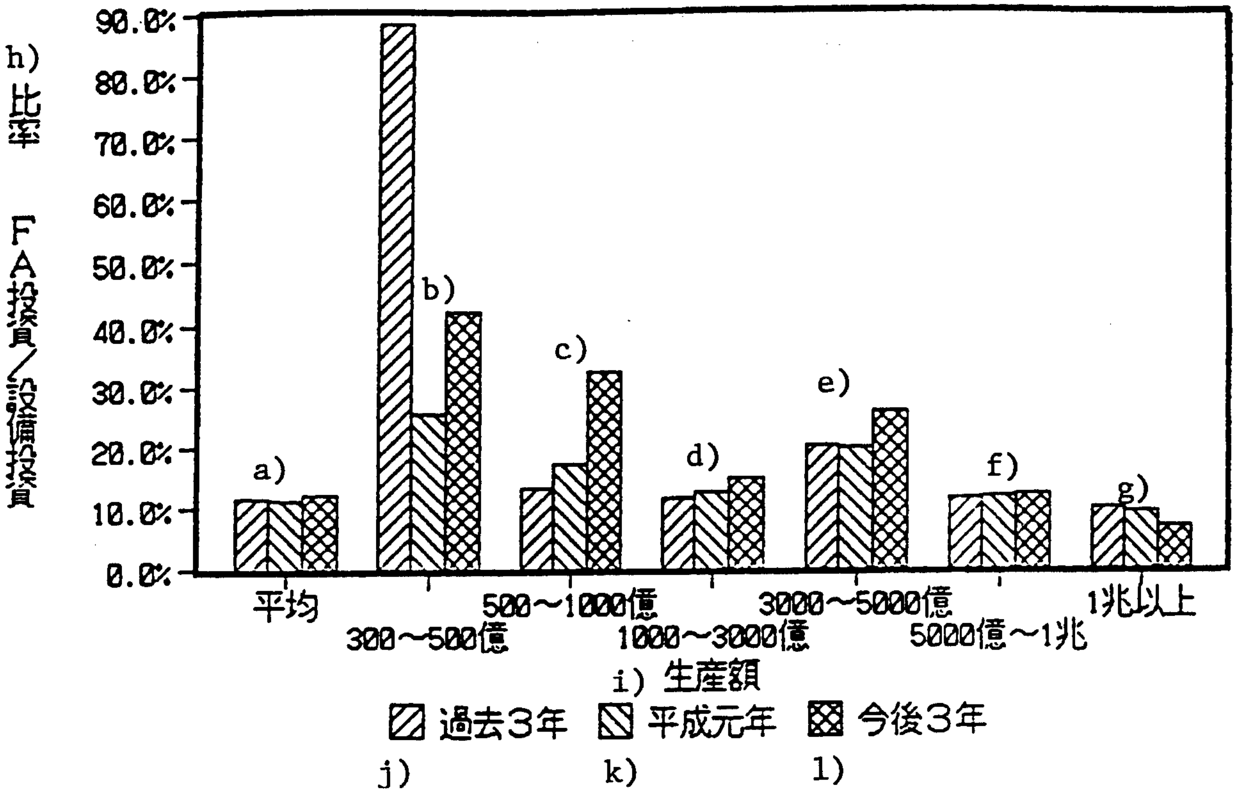
	Large companies (66)	Small companies (51)
Have implemented	86.4%	46.8%
Have not implemented	13.6%	53.2%

Figure 6-5.
Plant Investment and FA Investment (Large Companies)



Key:—(a) Average—(b) 30 to 50 billion—(c) 50 to 100 billion—(d) 100 to 300 billion—(e) 300 to 500 billion—(f) 500 billion to 1 trillion—(g) More than 1 trillion—(h) Unit=1,000—(i) Plant investment—(j) FA investment

Figure 6-6. Proportion of FA Investment (Large Companies)



Key:—(a) Average—(b) 30 to 50 billion—(c) 50 to 100 billion—(d) 100 to 300 billion—(e) 300 to 500 billion—(f) 500 billion to 1 trillion—(g) More than 1 trillion—(h) Proportion: FA investment/plant investment—(i) Total production—(j) Past three years—(k) 1989—(l) Next three years

Figure 6-12.
Factors in Implementation of Upgraded Manufacturing Methods

Factor	Large companies (69)	Small companies (49)
Shortened product life cycle	7	3
Diversification of products	43	33
Increased production	12	12
Compressed lead time	42	25
Stable product quality	15	14
Obsolescence of current method	10	11
New information/communication system	6	4
Integration of manufacturing by computer system	32	16
Domestic or foreign price competition	14	11
Sharp competition to develop new products	6	5
Shortage of key production personnel	10	4

5) Commercialization of FA: The Majority of the large companies responding intend to make a business of the FA they have accumulated in various manufacturing industries. Considered by sector, these of course include companies that have traditionally produced FA equipment, but with policies of diversification, companies in other sectors are included as well. Among smaller companies, on the other hand, there is no movement toward commercialization of FA except among those already manufacturing FA-related equipment.

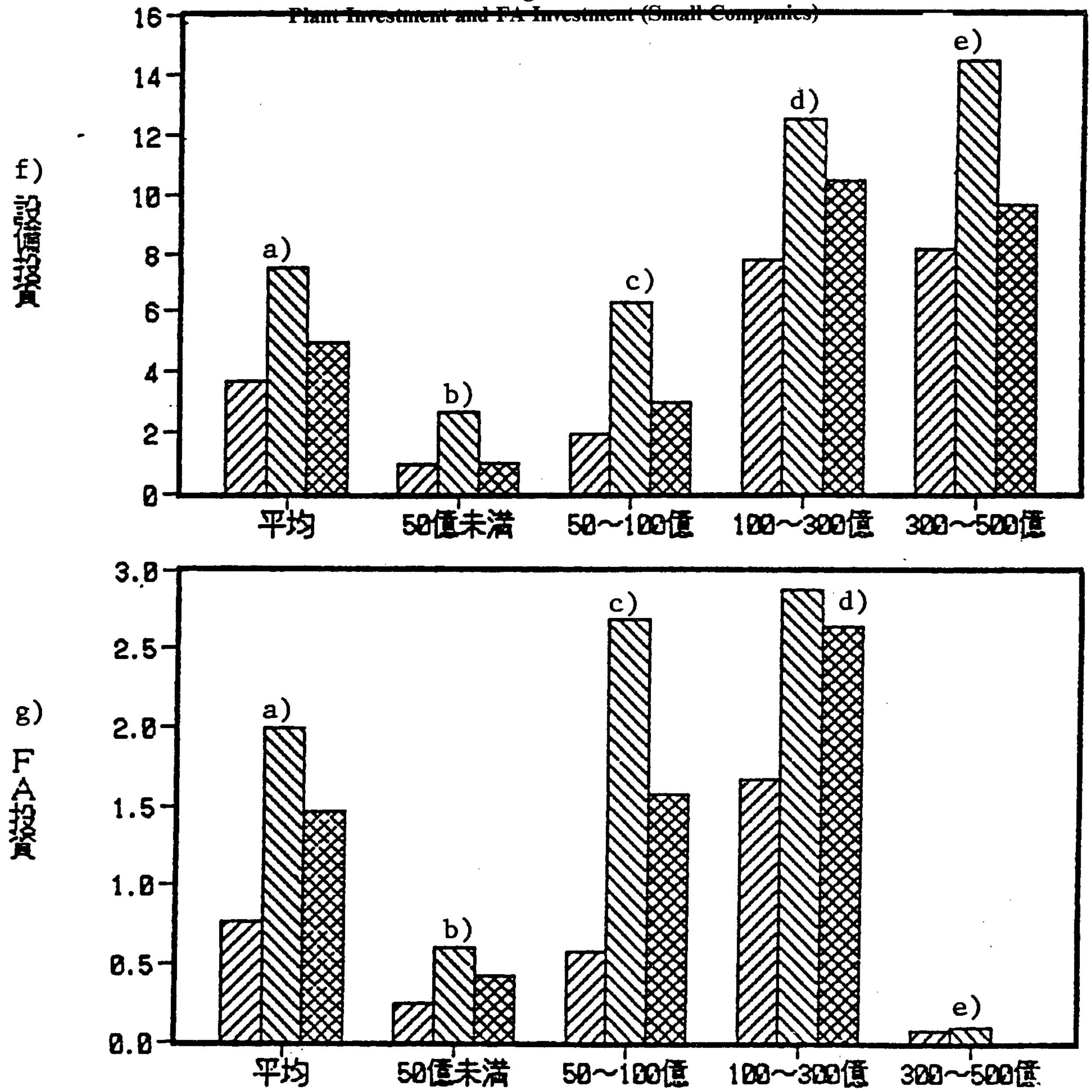
Figure 6-13.
Commercialization of FA

	Large companies (67)	Small companies (51)
Yes	53.6%	3.9%
No	46.4%	96.1%

6.2.2 Results and Interpretation of Responding Establishments

1) Breakdown of responding establishments: A breakdown of the business locations of companies that responded, by number of employees and annual production, is shown below.

Figure 6-7.
Plant Investment and FA Investment (Small Companies)



Key:—(a) Average—(b) Less than 5 billion—(c) 5 to 10 billion—(d) 10 to 30 billion—(e) 30 to 50 billion—(f) Plant investment—(g) FA investment

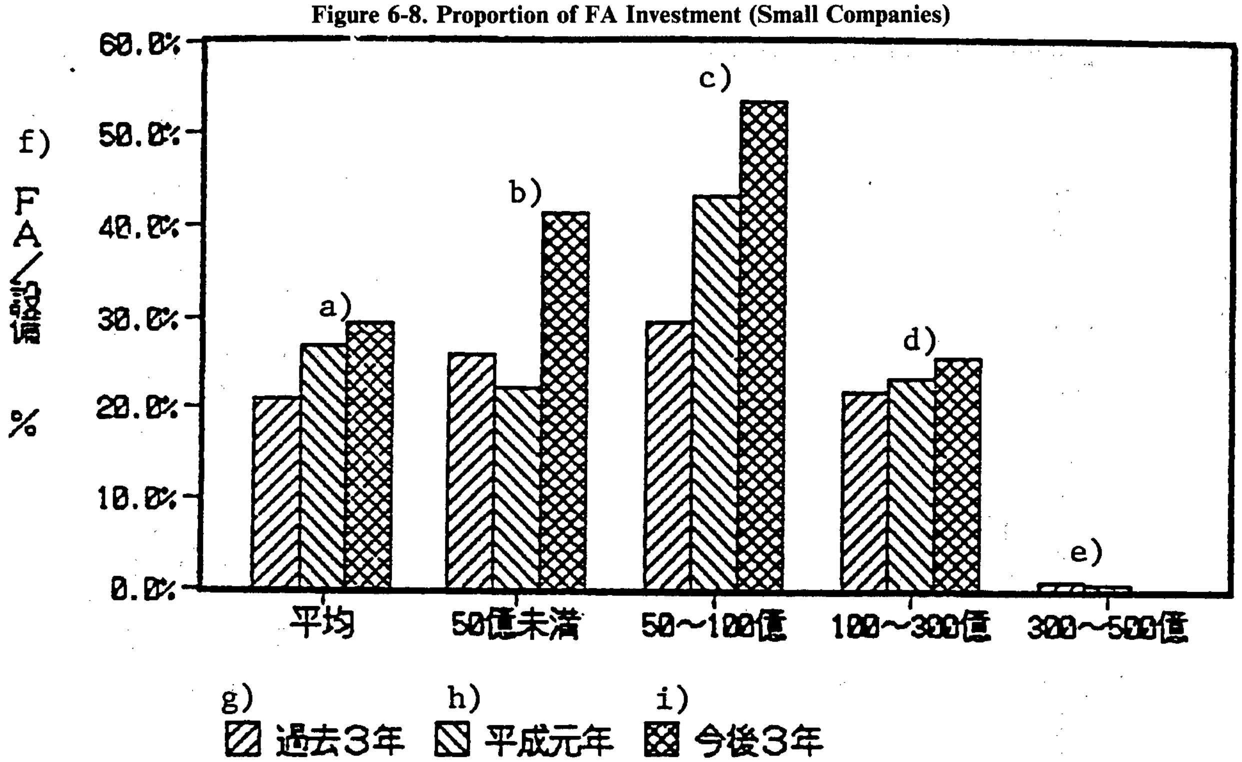
Table 6-1.
Number of employees

	Large companies (70)	Small companies (51)
Average	1,990	207
Largest	23,604	550
Smallest	70	28

Figure 6-14.
Total Production

Range	Percentage
Large companies (68 responses)	
1 to 5 billion	1.5
5 to 10 billion	4.4
10 billion to 50 billion	36.8

Figure 6-8. Proportion of FA Investment (Small Companies)



Key:—(a) Average—(b) Less than 5 billion—(c) 5 to 10 billion—(d) 10 to 30 billion—(e) 30 to 50 billion—(f) FA investment/plant investment—(g) Past three years—(h) 1989—(i) Next three years

Figure 6-14. Total Production (Continued)

Range	Percentage
More than 50 billion	57.4
Small companies (51 responses)	
Less than 1 billion	2.0
1 to 5 billion	51.0
5 to 10 billion	21.6
10 to 50 billion	25.5
More than billion	0.0

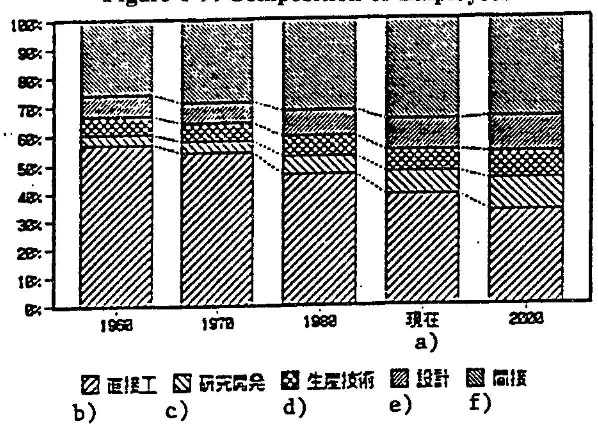
2) Factors influencing use of FA: Of the factors cited by establishments, whether large or small, for going ahead with FA, a large proportion consisted of (1) reduction of production lead time and (2) response to competition for development of new products.

Other important factors are, for large companies, improved product quality, and for smaller companies, use of robots and NC equipment in production facilities.

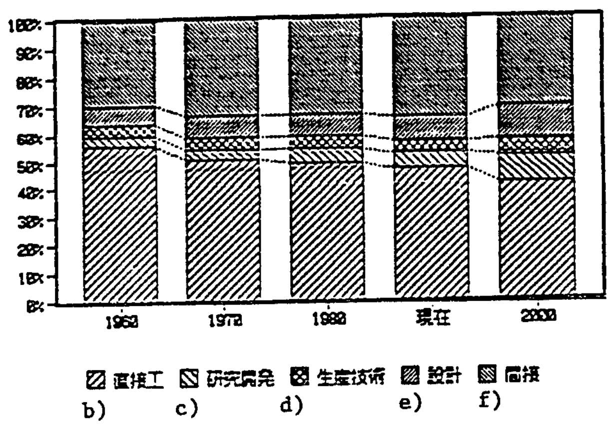
Figure 6-15. Influential Factors

Factor	Large Companies (69)	Small Companies (51)
Introduction or improvement of computers	21	10
Use of robots and NC equipment	21	21
Advent of new materials	1	1
Progress of advanced processing technology	10	5
Changed production quality or volume	22	17
Response to higher product quality	23	17
Reduced production lead time	30	19
Reduced nonproduction lead time	4	4
Competition for development of new products	28	22
Aging of key personnel	11	7
Changed consciousness of personnel	2	5
Shortage of skilled personnel	12	8
Shortage of technical personnel	10	14
Energy conservation	12	—
Networking with management	10	3
Other	2	—

Figure 6-9. Composition of Employees



g) 大企業



h) 中堅企業

Key:—(a) Present—(b) Direct production—(c) Research and development—(d) Manufacturing technology—(e) Design—(f) Indirect—(g) Large Companies—(h) Small Companies

3) FA Lines: Some 94% of the large establishments have introduced or in the process of introducing FA lines, but the figure for the smaller companies is 30%, less than half as high. However, more than 80% of them are at least considering introduction of FA lines, so introduction can be expected hereafter.

Figure 6-16. Introduction of FA Lines (%)

Category	Large companies (70)	Small companies (50)
Have introduced	80.0	22.0
Are introducing	14.3	8.0
Introduce in 2-3 years	4.3	18.0
Will consider introduction	1.6	36.0
Will not consider introduction	0.0	16.0

Figure 6-17. Satisfaction with FA Lines Introduced (%)

Category	Large companies (56)	Small companies (11)
Good	44.6	36.4
Average	42.9	54.5
Not satisfactory	10.7	9.1
Other	1.8	0.0

Figure 6-18. Purposes for introduction of FA Lines

Factor	Large companies (57)	Small companies (11)
Labor savings	49	10
Stable or improved product quality	31	7
Shortage of trained workers	3	—
Compressed lead time	19	2
Obsolescence of plant/machinery	3	1
Improved maintenance of plant/machinery	1	—
Diversification of products	21	4
Increased production	20	5
New distribution system to include product inventory	15	3
Other (specificy)	4	—

4) Production management: Management of production by means of computers has spread to nearly all large companies and 70% of the smaller companies; the use of computers has become a matter of course.

Figure 6-19. Implementation of Production Management by Computer

	Large companies (70)	Small companies (49)
Have implemented	98.6%	69.4%
Have not implemented	1.4%	30.6%

Figure 6-20. Adoption of MRP, JIT

	Large companies (68)	Small companies (48)
Have adopted	66.2%	45.8%
Adopted other method	11.8%	10.4%
Considering for future	19.1%	33.3%
Not considering	2.9%	10.4%
Other	0.0%	0.0%

5) FA Plant Investment

Investment in FA equipment has become the mainstay of plant investment in establishments of both large and smaller companies, and is expected to grow at a high rate. The proportion of computers, software and peripheral facilities is greater in large companies than in the smaller ones, and so it is thought integration is more advanced.

An inclination toward increased investment in information use (computers and software) can be seen even in the smaller companies.

Table 6-2. Average FA Plant Investment (unit=¥ 100 million)

	Large companies (56)	Small companies (49)
Past 3 years	33.0	2.0
Next 3 years	48.2	4.1
Growth rate	146%	205%

Figure 6-21. Implementation of Upgraded Manufacturing Methods

Large Companies		
	Past 3 years	Next 3 years
FA equipment	47.0%	47.8%
Computers	8.0%	8.2%
Software	5.8%	5.2%
Peripheral Facilities	10.0%	9.9%
Site facilities	13.6%	9.8%
Smaller Companies		
	Past 3years	Next 3years
FA equipment	98.3%	54.7%
Computers	0.5%	13.0%
Software	0.3%	15.2%
Peripheral Facilities	0.3%	10.7%
Site facilities	0.3%	5.3%

6) Effect of introduction of FA: The introduction of FA is effective, in that 100% of both large and small companies that had introduced FA said either that it had an effect or an effect was expected.

Figure 6-22. Effect of Introduction of FA (%)

	Large companies (60)	Small companies (33)
Has had effect	90.0	78.8
Effect expected	10.0	21.2
No effect	0.0	0.0

7) Use of outside entities: Given the shortage of human resources, both large and smaller companies have considered the use of outside entities when putting FA to use. More than half the smaller companies have considered that course.

Figure 6-23. Use of Outside Entities (%)

	Large companies (68)	Small companies (38)
Have considered	33.8	52.6
Build in-house	64.7	42.1
Other	1.5	5.3

7.FA-related Vocabulary

Artificial Intelligence (AI): Use of computers to imitate human intelligence, thought or decision-making processes, such as learning, optimization, recognition, classification, deduction, correction and improvement, or to the same results as those processes.

Automatic (automated) Guided Vehicle (AGVS): A unmanned vehicle that is loaded with items related to production (workpieces, tools etc.) and, guided by some means, transports them to the proper places within the factory. Those with rails are classified as Rail Guided Vehicles and those without rails are called Automatic Guided Vehicles. Battery-powered vehicles without rails have become more common recently.

Automatic Warehouse System: A warehouse where, in order to temporarily store and control parts used in the manufacturing process, the parts are automatically taken into or out of stock, stored and controlled in pallets or buckets in the units dealt with in production. Stacker cranes are used to automatically move the pallets into and out of vertically arrayed racks that number from tens to tens of thousands.

Computer Aided Design (CAD): Design work using computer displays and other input/output equipment. CAD functions include drawing, form modelling, technical calculation, simulation etc.

Computer Aided Engineering (CAE): Comprehensive processing of information necessary for production of goods, and prior evaluation of product characteristics and production processes, using computers. An integration of CAD, CAM and simulation of product characteristics and production processes using computers.

Computer Aided Manufacturing (CAM): Provision of CAD-generated drawings and models of products for the design and manufacturing processes, and computer support of work plans and process plans for manufacturing. This is also called computer-aided preparation for production, and the software used is called production preparation software. It includes NC programming, robot movement programs, assembly programs, testing

programs and other work plans, as well as equipment selection, tool selection, determination of production processes, scheduling of transport vehicles and other process plans. CAM can be combined with CAD in an effort to comprehensively automate processes from design through manufacturing; this is called CAD/CAM.

Computer Aided Testing (CAT): Testing of products using computers. Automatic testing through connection of computers to equipment that checks the measurements and performance of products.

Computer Integrated Manufacturing System (CIM): Where FMS is flexible automation, primarily in the manufacturing sector, and FA is an extension of that concept, CIM is a matter of linking all production-related information by networks, integrating databases, and using computers to comprehensively control and manage manufacturing information with a system that optimizes manufacturing activity.

Data Base: An accumulation of data in which related facts and knowledge are taken as single units and efficiently searched or updated without affecting the independence of data elements.

Factory Automation (FA): The comprehensive and flexible automation of an entire factory.

Factory Automation Interconnection System (FAIS): A communications protocol being developed in Japan, at MITI's initiative, following mini-MAP standards.

Flexibility: The flexibility or versatility of manufacturing systems to deal with changes, in terms of space or time, to the volume or type of products produced, with no loss of efficiency.

Flexible Manufacturing Cell (FMC): A single NC machine tool equipped with a workpiece stocker and automatic feed or delivery and removal equipment, a tool exchanger and so on, capable of automatic machining of multiple products in a nearly unmanned state for long periods, and capable of machining parts for a specific purpose.

Flexible Manufacturing System (FMS): A system in which all production facilities are comprehensively controlled and managed by computer, capable of mixed production of a range of similar products and having system functions that can be changed by minimum human intervention (a change of software, in many cases). It can respond to diversified demands for system configurations that differ from the original without a drop in productivity.

Flexible Transfer Line (FTL): Unlike transfer lines that are used primarily for mass production of a single item, program functions, NC functions and gang head exchange functions are added to the processing stations that make up the traditional transfer line, in order to efficiently handle either minor changes in the specifications of items produced, or mixed production of items with similar specifications, thus increasing the flexibility of the line as a whole without reducing productivity. However, the high level of flexibility seen in FMS is not intended.

Host Computer: When different types of computers or terminals make up an information processing system, the host computer is the one with the greatest general-purpose processing capability; it acts as the nucleus for execution of processes within the system, or provides control for achievement of the objective.

International Electrotechnical Commission (IEC): The electrical specialists working group of ISO (the International Organization for Standardization), which carries out the work of designing international standards in the fields of electricity and electronics.

International Organization for Standardization (ISO): An organization that has developed and promoted international standards to facilitate the international exchange of goods and services, and to heighten international cooperation in the fields of intellectual, scientific and technical activity.

Job Shop Type Production: A mode of production to manufacture, flexibly and with high productivity, small numbers of a wide variety of goods, in order to produce just the necessary amount at the scheduled time.

Just in Time System (JIT): A system to deliver needed goods in the quantity needed to the placed where they are needed at the time needed. In the traditional distribution system, technical and economic possibilities were taken into consideration and economical lot sizes were established, and goods were produced and transported in lots. However, that led to inefficiencies of overproduction, storage, transport and inventory, and so the JIT system was based on the principle of producing needed items in just the quantity needed for subsequent processes. The kanban was introduced as a tools of the system, and the work time was reduced through schedule changes.

Kanban Managing System: A method of implementing the JIT system. This is a method conceived by Toyota Motors, now widely understood throughout the world. Such information as the production volume, time, method and order, or the transport volume, time destination, location and transport container are entered on a piece of paper in a plastic envelop. When an item requires subsequent processing, the kanban from the prior processing goes with it. By this means, only needed items are produced and transported when they are needed.

Local Area Network (LAN): LAN's integrate, into one or more high-speed communication circuits, intercommunications among multiple devices with communications functions (such as computers, terminals and FA machines) that are distributed to different locations within a company or other entity.

Manufacturing Automation Protocol (MAP): A protocol used in LAN's for FA, proposed by General Motors of the United States. MAP is based on the basic standards of OSI.

Machining Center (MC): A numerical control machine tool equipped with an Automatic Tool Changer (ATC) or division mechanism, and capable of various types of machining, such as milling, drilling or tapping, of multiple faces without removal of the workpiece. They are classified as horizontal or vertical on the basis of the main spindle.

Material Requirements Planning (MRP): An integrated production management system characterized by the division of items covered by planning management into the autonomous demand and subordinate demand categories. Autonomous demand items (such as finished goods) are covered by standard production plans based on forecasts and orders; subordinate demand items (such as component parts) are calculated from the standard production plans for autonomous demand items. Originally MRP simply meant material requirements planning, but it has gradually developed from there and has come to be understood as a new, integrated production management system.

Monitoring: Efforts to determine whether a system or machine is performing its prescribed functions normally, and to discover any abnormal situations.

NC (Numerical Control) Machine Tools: Machine tools that are numerically controlled by NC devices.

Open Systems Interconnection (OSI): OSI is an international standard network architecture promoted by ISO and CCITT (International Telegraph and Telephone Consultative Committee) for the purpose of interconnection of different types of computers. In the basic reference model, the computer network is an abstract model, with seven layers, composed of various elements such as an open system, physical media and application processes.

Point of Sales Information Management (POS): A system for sending sales information collected item-by-item at registers with automatic optical readers, as well as various other types of data generated during stocking etc., to a computer so it can be processed and reported so as to be effectively used in accordance with the purposes of the sectors involved.

Production Control: This encompasses activities to supply the customer with the products desired at the time requested, in the amounts needed and at market prices. Broadly defined, it is a combination of such functions as quality control, schedule control, cost control, materials control, outside order management, transport control, plant control, tools control and safety control. These operations are normally carried out in a cycle from forecasting to receipt of orders to materials procurement, to production to delivery. Narrowly defined, it is the planning of what, when and how many to produce, the planning of capabilities to implement that production, and the management of work in accordance with that planning. It includes such concepts, methods and systems as parts-centered production, the kanban system, MRP, MRP II, the production sequence method and OPT (Optimized Production Technology).

Programmable Controller (PC): A type of sequence controller in which the content of the control can be varied. The term refers primarily to electronic controllers composed of semiconductor devices like microprocessors. They are also called PLC (Programmable Logic Controllers); input/output and control methods have tended to become more advanced.

Protocol: Rules determining the content and format of sequence and control information for the transmission and reception of information between devices connected by communications circuits.

Simulator: A specialized system or software to perform simulation.

Technical and Office Protocol (TOP): A protocol for LAN's used for office automation and technical information, proposed by Boeing Corp. of the United States.

Total Quality Control (TQC): Quality control implemented across all levels of company activities. "Quality control" (QC) refers to methods to economically produce goods and services with the quality demanded by the buyer.

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